Framework for Multi-Resolution Analyses of Advanced Traffic Management Strategies

Mohammed Hadi, Thomas Hill, and Vladimir Majano

Agenda

- Review of Florida Traffic Analysis Handbook
- Introduction to Multi-Resolution Modeling (MRM)
- MRM Framework
- Case Study: I-95 Managed Lane Corridor

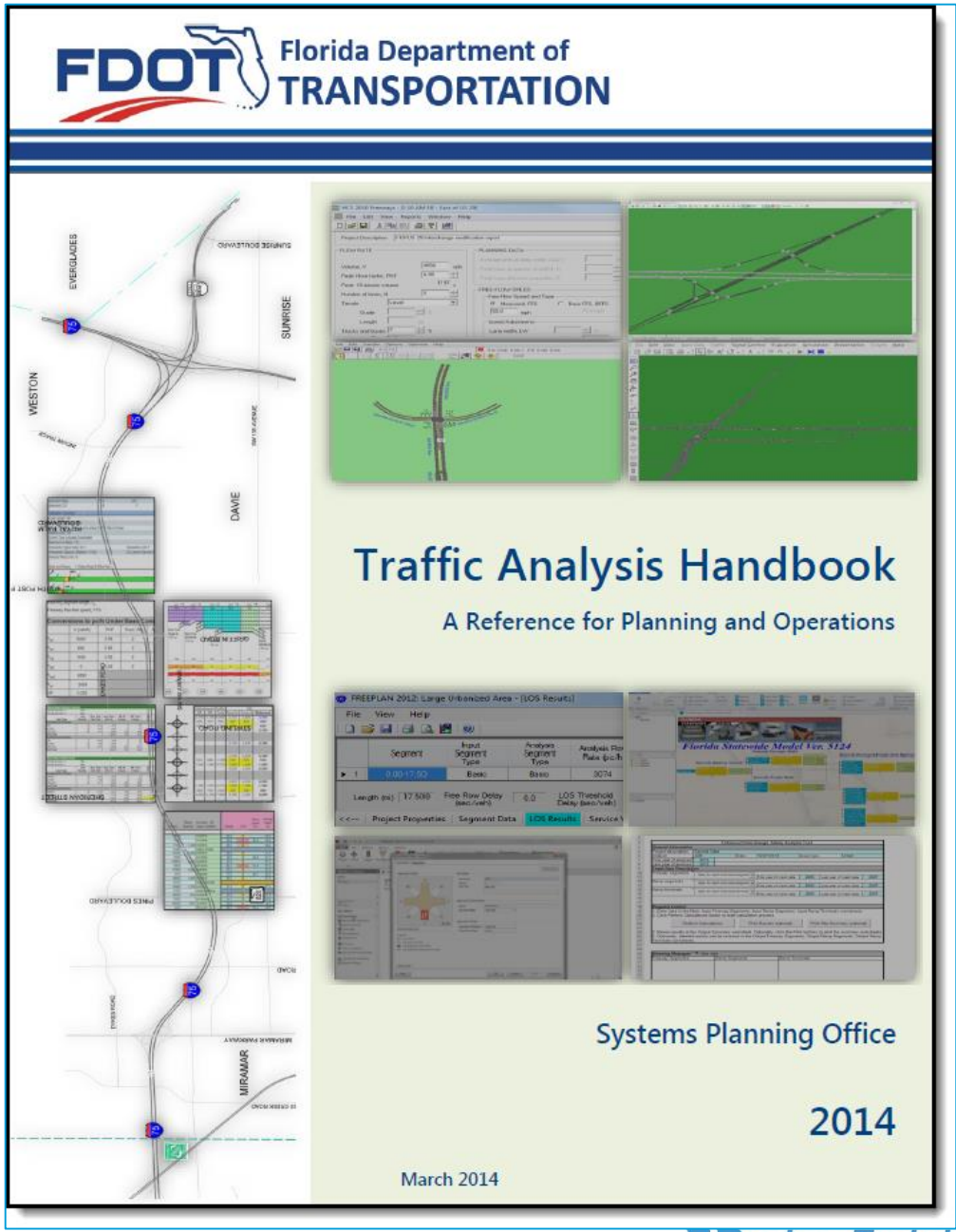
Role of Analysis Tools

- Identification of deficiencies in design and/or operations
- Support assessing system, corridor, and segment performance
- Impacts of influencing factors (incidents, weather, etc.)
- Assessment of advanced strategies
- Prioritization of alternatives
- Forecasting future conditions
- Off-line and real-time support of traffic operations and management
- Connected and automated vehicle modeling
- Hardware, software, and driver in the loop

Planning for Operations (Source: FHWA)

Transportation Planning Needs	OPERATIONAL ANALYSIS TOOLS/METHODS						
	Sketch Planning Tools	Deterministic Models	Travel Demand Forecasting Models	Simulation	Archived Operations Data	Operations-Oriented Performance Metrics	Traffic Signal Optimization Tools
Needs Assessments/ Deficiency Analysis		•	•	•	•	•	•
Preliminary Screening Assessments	•					•	
Alternatives Analysis	•		•	•		•	
Strategic ITS Planning	•		•			•	
Project Scoring/ Ranking/ Prioritizing		•	•			•	
Corridor and Environmental Analysis		•	•	•		•	•
Planning for Nonrecurring Congestion	•		•	•	•	•	
Performance Monitoring		•			•	•	•
Evaluations of Developed Projects	•		•		•	•	

2017 Design Training Expo


FDOT
Florida Department of
TRANSPORTATION
Traffic Analysis Handbook
A Reference for Planning and Operations
Systems Planning Office
2014
March 2014

Chapters

1. Introduction
2. Methodology
3. Analysis Area
4. Tool Selection
5. Data Collection
6. Analytical Tools
7. Microsimulation Analysis
8. Alternatives Analysis
9. Documentation

Applicable Traffic Analysis

- Corridor studies,
- Interchange Access Requests (IARs)
- Project Development and Environment (PD&E) studies.

Level of Analysis

- Generalized planning (sketch-level)
- Conceptual planning and Preliminary Engineering
- Design
- Operational

Chapter 4
Analysis Tool Selection

Traffic Tools used in Florida:

- Generalized Service Volume Tables (GSVT)
- LOSPLAN
- HCM/HCS
- Synchro and SimTraffic
- SIDRA INTERSECTION
- CORSIM
- VISSIM

Recommendations:

- Apply one set of tools consistently
- Select appropriate tools based on
  - Level of analysis effort
  - Degree of detail
  - Limitation of the tool
- More than one tool might be needed

Fig. 4-1 Categories of Traffic Analysis Tools

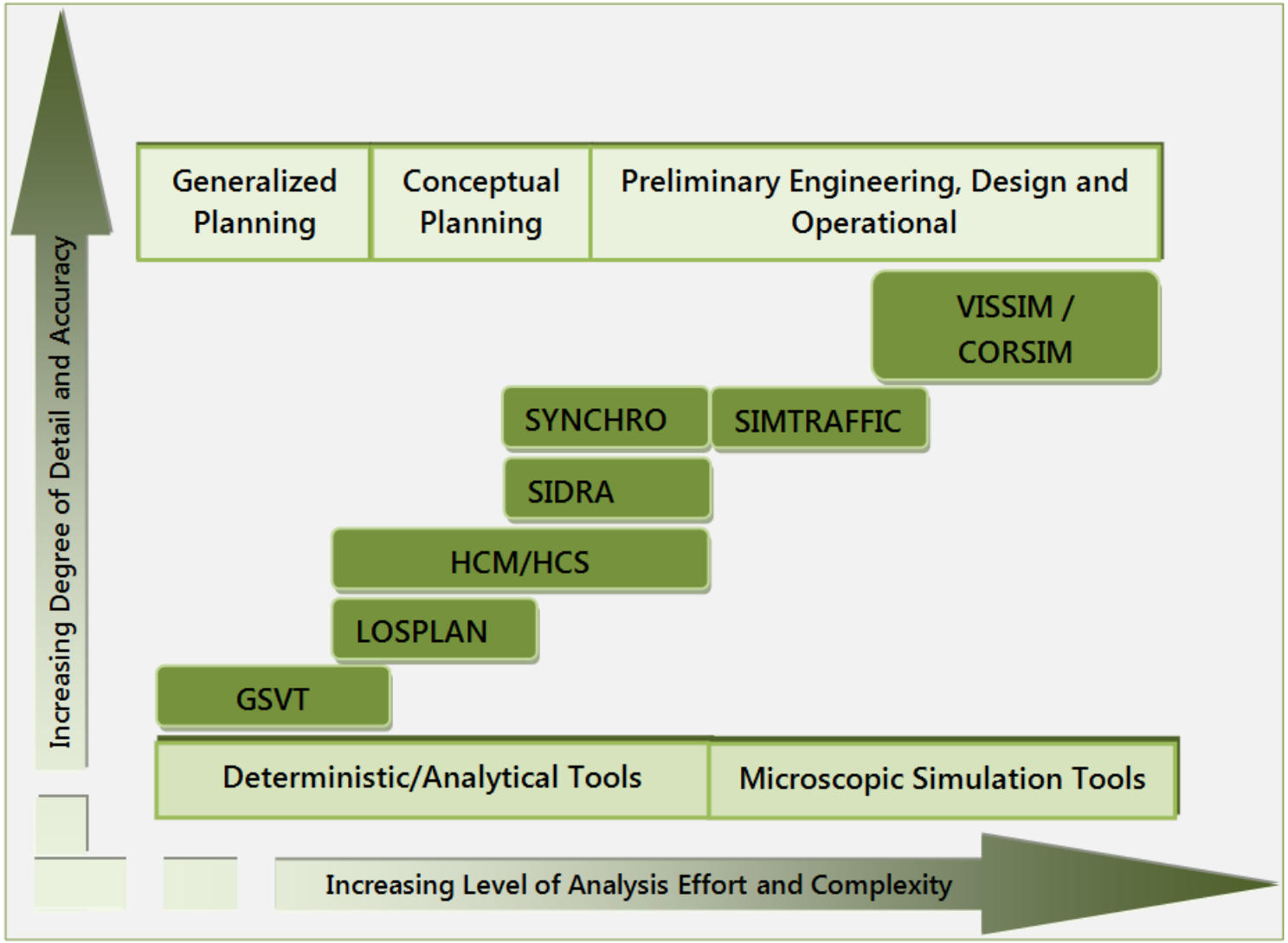


Table 4-1 Use of Traffic Analysis Tools

Analysis Type	Level of Detail	Level of Analysis	Analysis Tool
Sketch Planning	Analyzing system elements to obtain general order-of-magnitude estimates of performance based capacity constraints and operational control	Generalized Planning	GSVT, LOSPLAN, HCM/HCS
Deterministic	Analyzing broad criteria and system performance based on geometric and physical capacity constraints; operational systems such traffic control and land use	Conceptual Planning & Preliminary Engineering; Design; Operation	LOSPLAN, HCM/HCS, Synchro, SIDRA
Travel Demand Modeling	Analyzing regional travel demand patterns, land use impacts and long range plans. Outputs of demand models are applied in analytical and microscopic analysis	Conceptual Planning	Cube Voyager
Microscopic Simulation	Analyzing system performance based on detailed individual user interactions; geometry and operational elements	Preliminary Engineering; Design; Operation	CORSIM, VISSIM, SimTraffic

Which Tool is Appropriate ?

- It depends on the project complexity, goals, time, budget and performance measures
- Tradeoff between resources versus decisions
- Review tool capabilities

Table 4-2 Traffic Analysis Software by System Element

Facility	Level of Analysis	Project Need	Performance MOE	Recommended Software
Limited Access	Generalized Planning	Determining a need for additional capacity	LOS	GSVT, LOSPLAN
	Conceptual Planning	Determining number of lanes	LOS	LOSPLAN, HCS
	Preliminary Engineering and Design	Determining how the facility will operate	LOS, density, speed, Travel time	HCS CORSIM, VISSIM
	Operational	Determining how well the facility operates	LOS, density, speed, Travel time	HCS CORSIM, VISSIM
Interchanges	Conceptual Planning	Determining capacity of the weaving segment	Flow rate, LOS	HCS
	Preliminary Engineering and Design	Determining capacity of the weaving segment or ramp merge/diverge	Density, speed, LOS	HCS
		Evaluating effect of a queue backup from the ramp terminal to the weaving operation	Queue length	SYNCHRO, VISSIM, CORSIM
		Analyzing weaving from ramp terminal to the nearest signalized intersection	Speed, density	VISSIM/CORSIM
		Evaluating the operation of the entire interchange	Density, speed,	SYNCHRO, CORSIM, VISSIM
	Operational	Evaluating weaving operation	LOS, density	HCS, SYNCHRO, VISSIM, CORSIM
Urban Arterials	Generalized Planning	Determining a need for additional capacity	LOS	GSVT, LOSPLAN
	Conceptual Planning	Determining number of lanes	LOS	LOSPLAN, HCM/HCS
	Preliminary Engineering and Design	Determining how the facility will operate	Speed	HCS
		Optimizing signals	Control delay, queue, V/C ratio	SYNCHRO/SIMTRAFFIC
	Operational	Coordinating traffic signals	Travel time, speed	SYNCHRO
		Evaluating existing signal timing plans	Travel time, speed	HCS, SYNCHRO
		Checking the effect of technology application or traffic demand management strategy	Travel time, speed	SYNCHRO/SIMTRAFFIC, VISSIM,CORSIM
Rural two-lane highways and Multilane highways	Generalized Planning	Determining a need for additional capacity	LOS	GSVT, LOSPLAN
	Conceptual Planning	Determining number of lanes	LOS	LOSPLAN, HCS
	Preliminary Engineering and Design	Determining how the facility will operate	LOS	HCS
	Operational	Determining how well the facility operates	LOS	HCS
Intersections	Conceptual Planning	Determining a need for additional intersection capacity	LOS, V/C, delay	HCS, SYNCHRO
	Preliminary Engineering and Design	Designing isolated intersection	LOS, V/C, delay	HCS, SYNCHRO
		Analyzing closely spaced intersections	LOS, V/C, delay, queue length	SYNCHRO/SIMTRAFFIC
		Analyzing unconventional (or complex) intersection	LOS, V/C, delay, queue length	CORSIM, VISSIM
		Analyzing multimodal interactions	LOS	VISSIM, HCS
	Operational	Evaluating the performance of signalized intersection	LOS, V/C, control delay, queue, ,Phase Failure	HCS, SYNCHRO
Roundabouts	Conceptual Planning	Evaluating the need for roundabout	V/C, LOS	SIDRA, HCS
	Preliminary Engineering and Design	Analyzing roundabout	V/C, LOS	SIDRA, HCS, SYNCHRO
	Operational	Evaluating the performance of roundabout	V/C, LOS, delay	SIDRA, HCM, SYNCHRO, VISSIM

Table 4-2. Traffic Analysis Software by System Element

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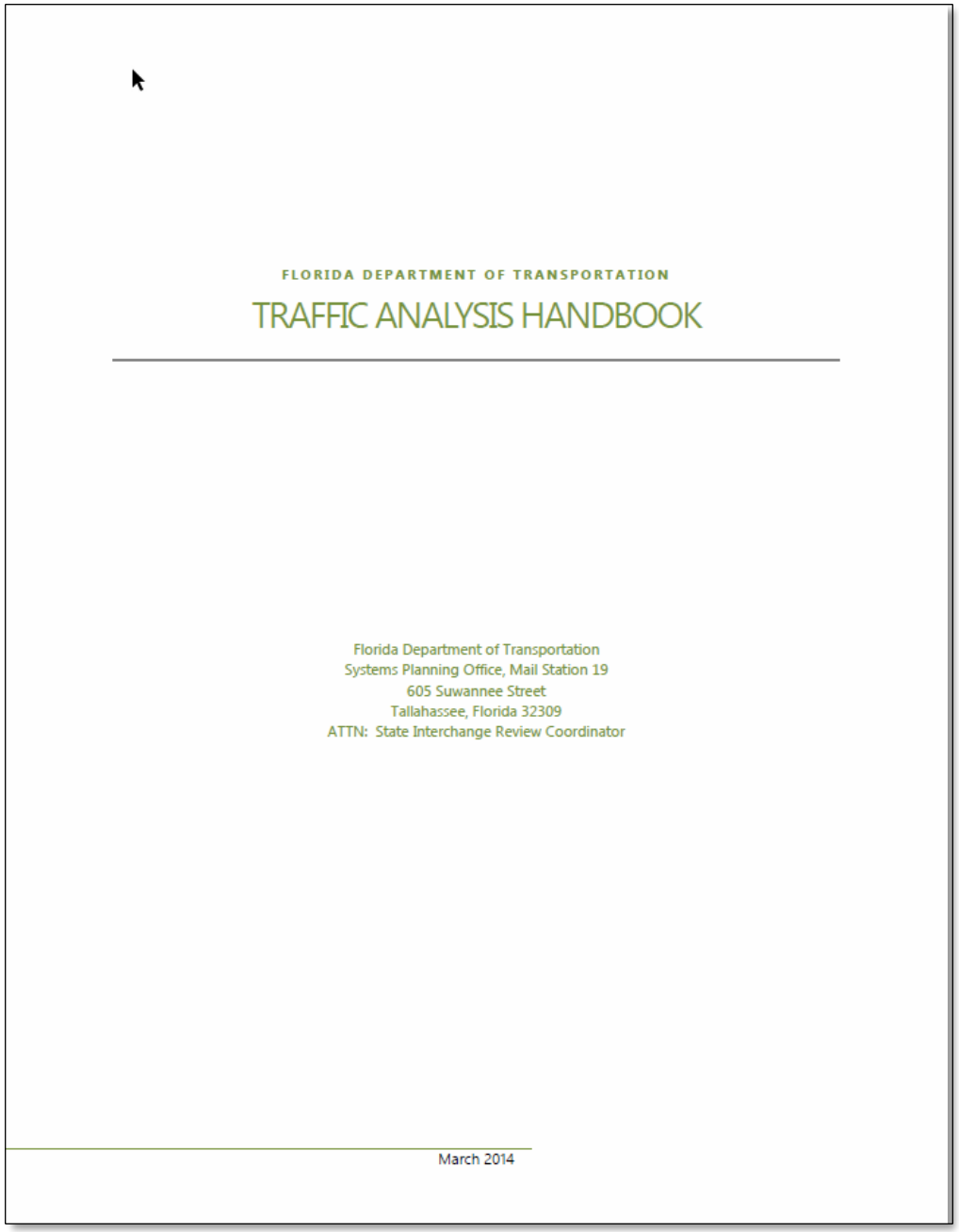
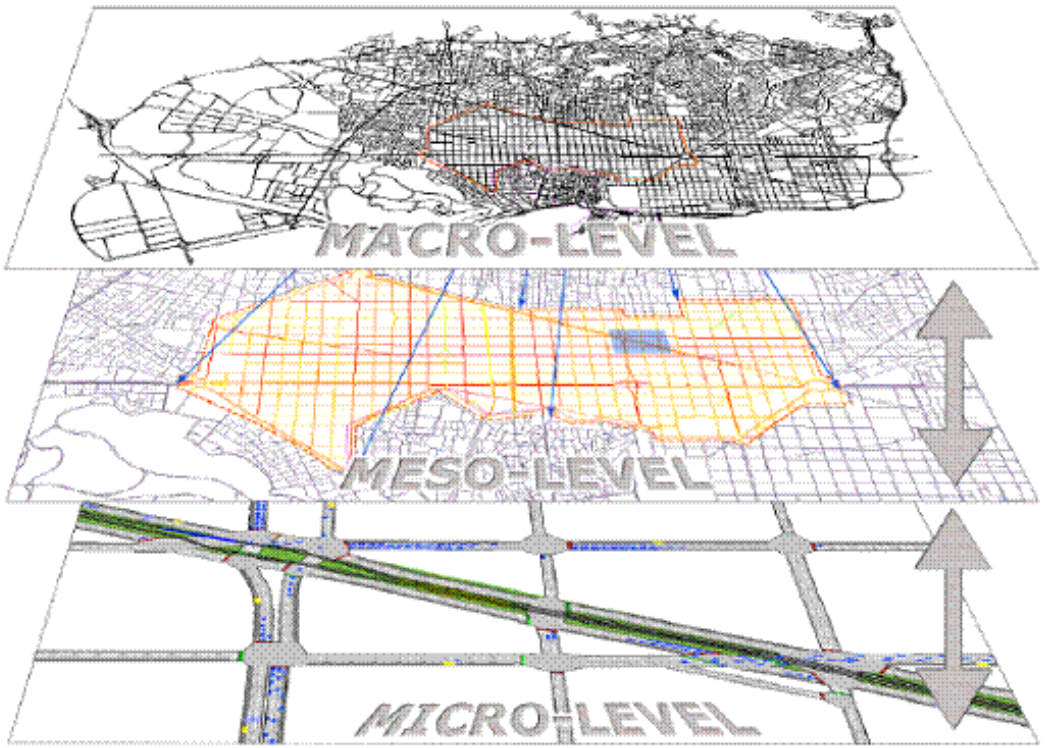


Traffic Analysis Handbook (2014) does not include:

- Multi-Resolution modeling
- Traffic Analysis on Managed Lanes
- Multimodal Transportation Alternative Studies

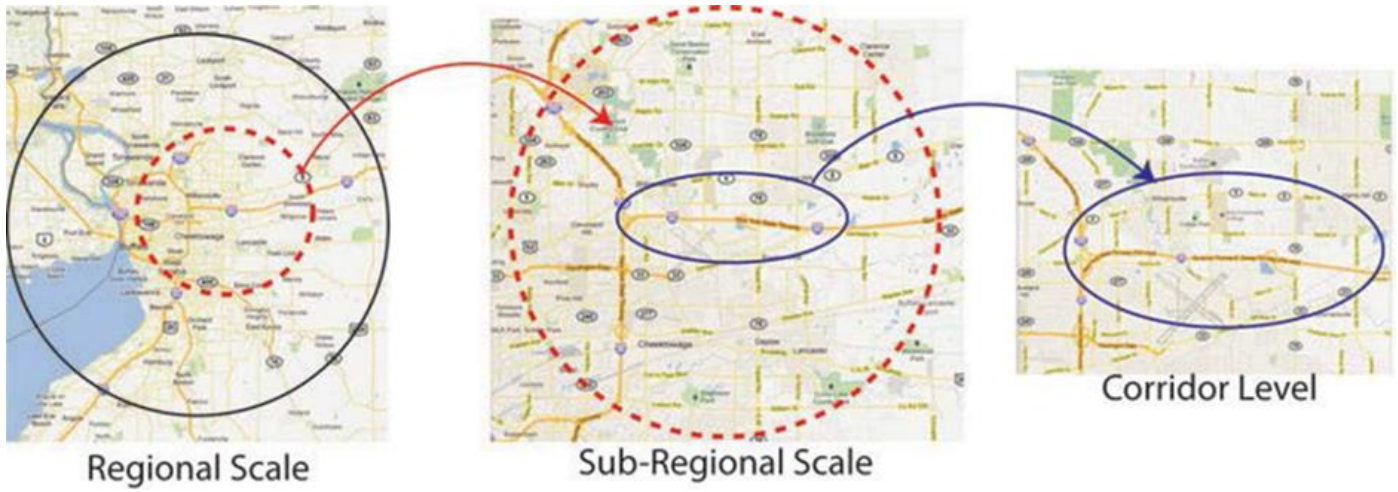
Needs for Multi-Resolution Modeling Framework

- Modeling congested conditions
- Multi-modal modeling
- Support planning for operations and operational aspects of TSM&O
  - Managed Lanes & Dynamic Pricing
  - Advanced Signal Control
  - Smart Work Zones
  - ATDM
  - ICM
  - ITS
  - Other operational strategies



Multi-Resolution Modeling

Macroscopic | Mesoscopic | Microscopic



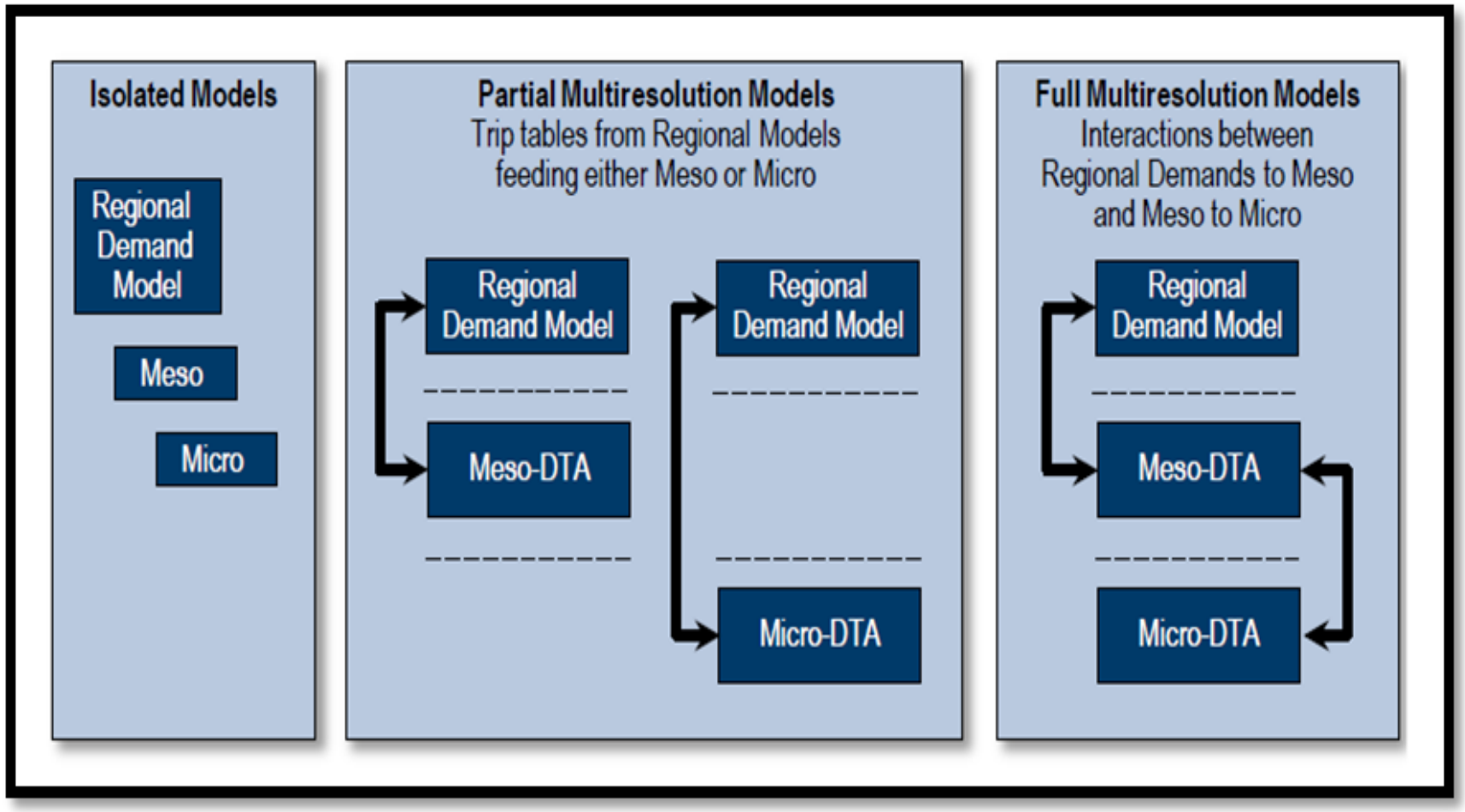
Dynamic Traffic Assignment (DTA)

- Cube Voyager
- VISUM (DTA)
- HCM/HCS
- FITSEVAL

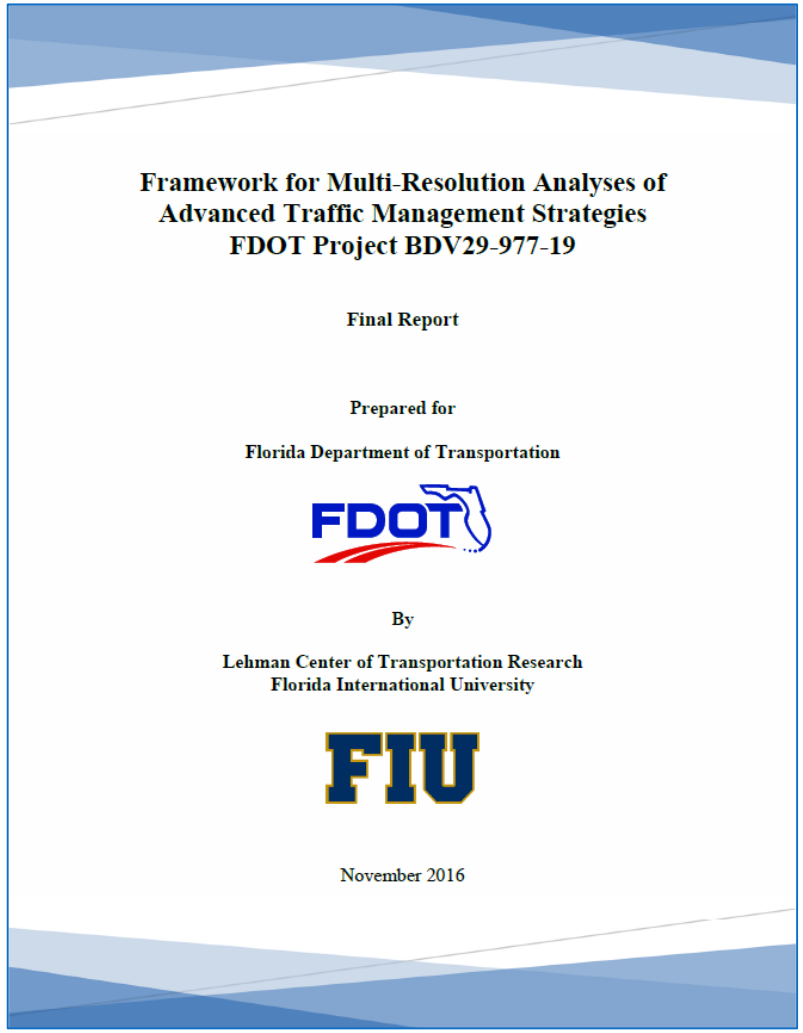
- Cube Avenue (DTA)
- Dynasmart (DTA)
- DynusT (DTA)
- DTALite (DTA)
- DIRECT (DTA)

- VISSIM (DTA)
- CORSIM
- AIMSUN

Multi-Resolution Modeling Types



Research Objectives


Framework for Multi-Resolution Analyses of
Advanced Traffic Management Strategies
FDOT Project BDV29-977-19

Final Report

Prepared for

Florida Department of Transportation

FDOT

By

Lehman Center of Transportation Research
Florida International University

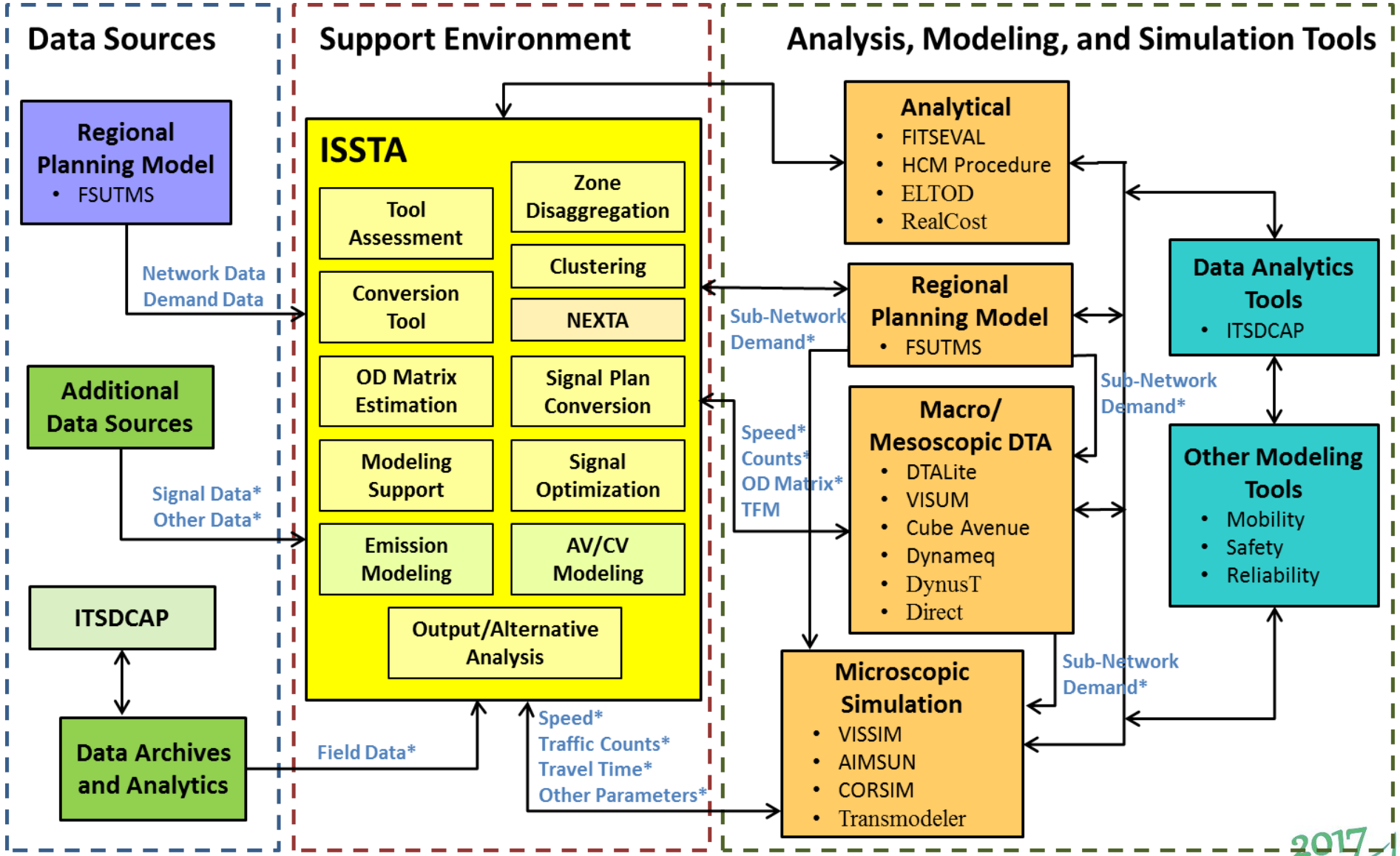
FIU

November 2016

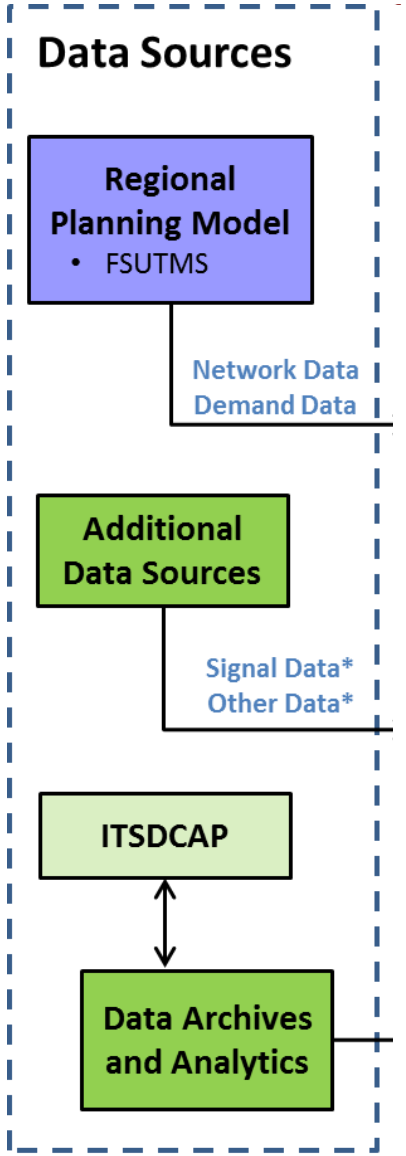
- Investigate the ability of combinations of tools in analyzing congestion and advanced strategies
- Recommend a framework for use in support of agency analysis and modeling processes
- Apply and assess the utilization of tools in the modeling of use cases

2017 Design Training Expo

Proposed MRM Framework Components



Proposed MRM Framework Components



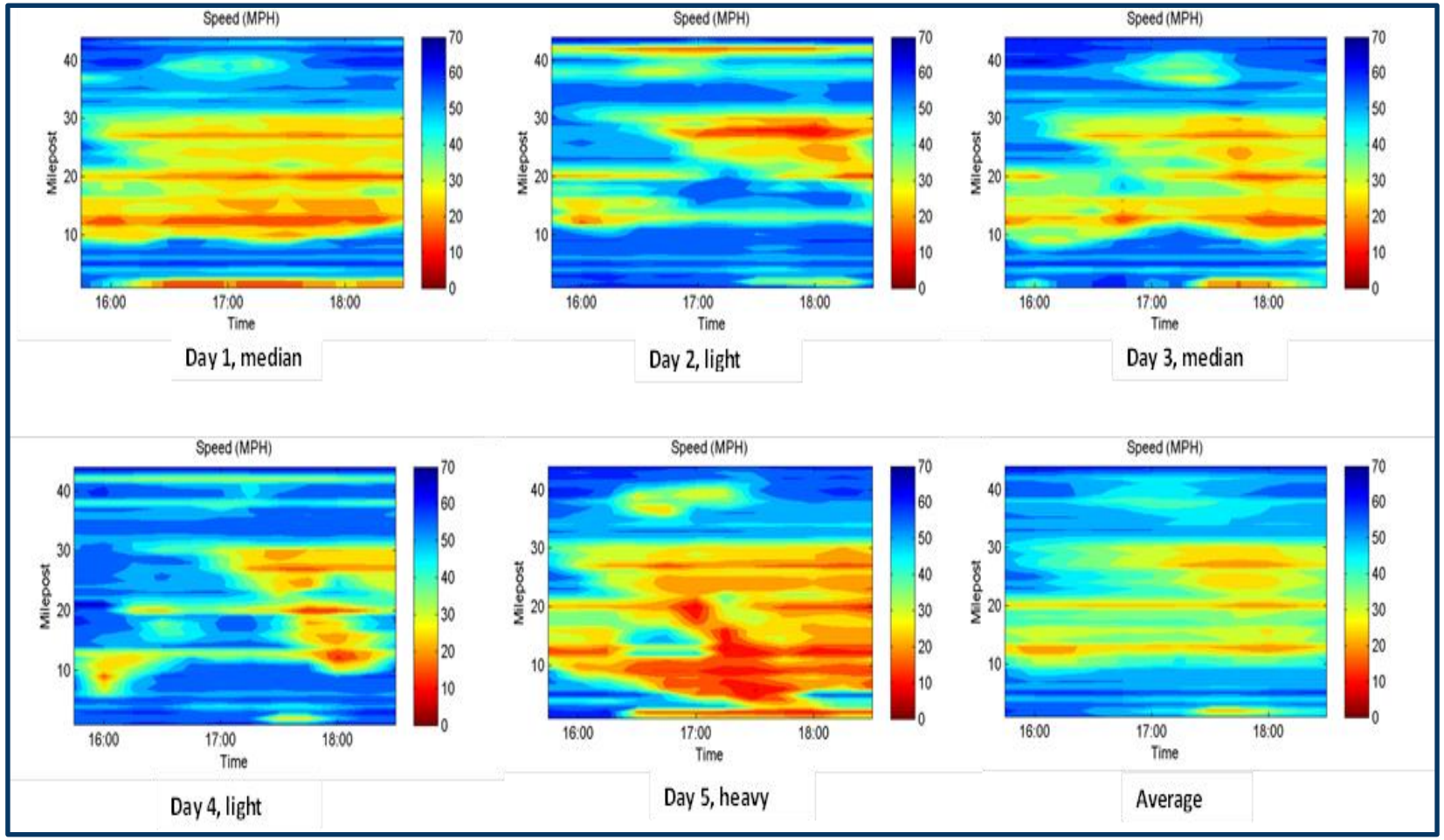
Data Needs

- Data from multiple sources both conventional and new
- Increased emphasis on data from multiple days
  - Allow identifying different operational conditions (operational scenarios)
  - Allow identifying representative days
  - Allow isolating out unusual days and days with bad data
  - Allow identification of system reliability

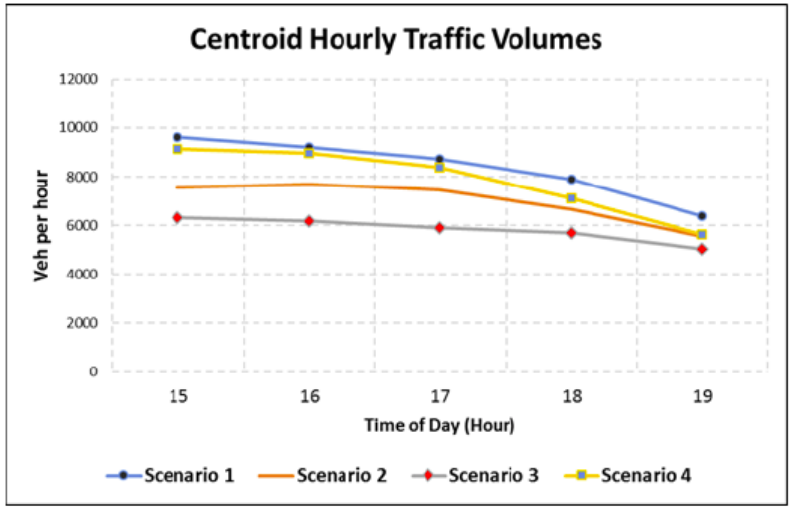
Data from Multiple Sources

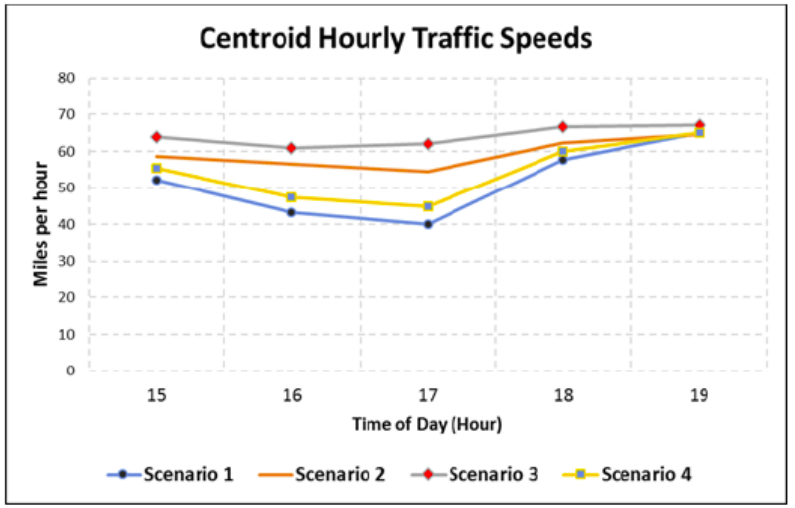
- Traffic operation detector and incident data
- Planning office data
- Private sector data
- AVI data (Bluetooth, Wi-Fi, ETC)
- Weather data
- Managed lane dynamic congestion pricing rates
- Work zone data
- Crash data (CAR System and Signal4)
- Signal control, ramp metering, and other ATDM parameters
- Freight data
- transit data
- Freight data
- Connected/Automated vehicles, and connected travelers

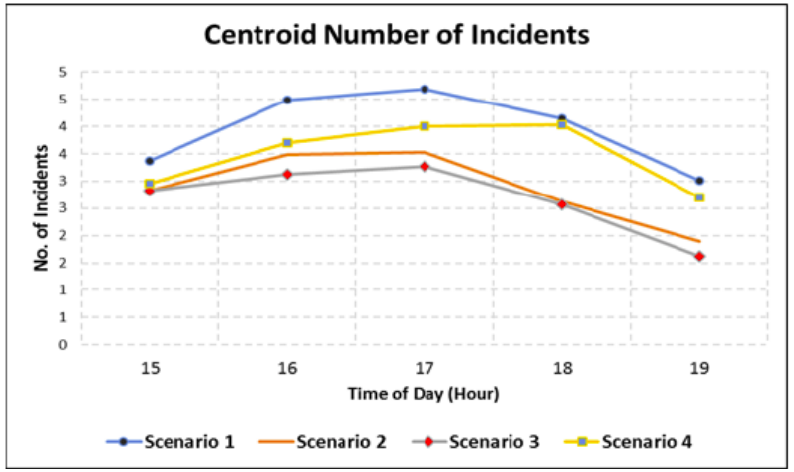
Day-to Day Variation (I-95 Miami)

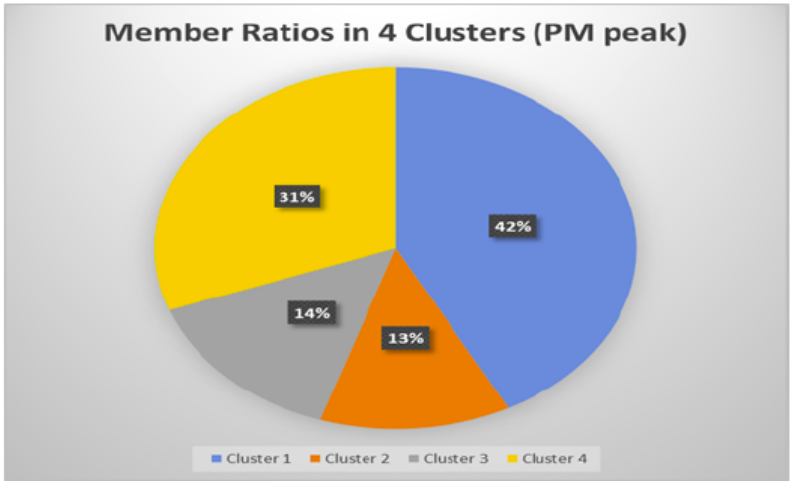


Phoenix Testbed Clustering





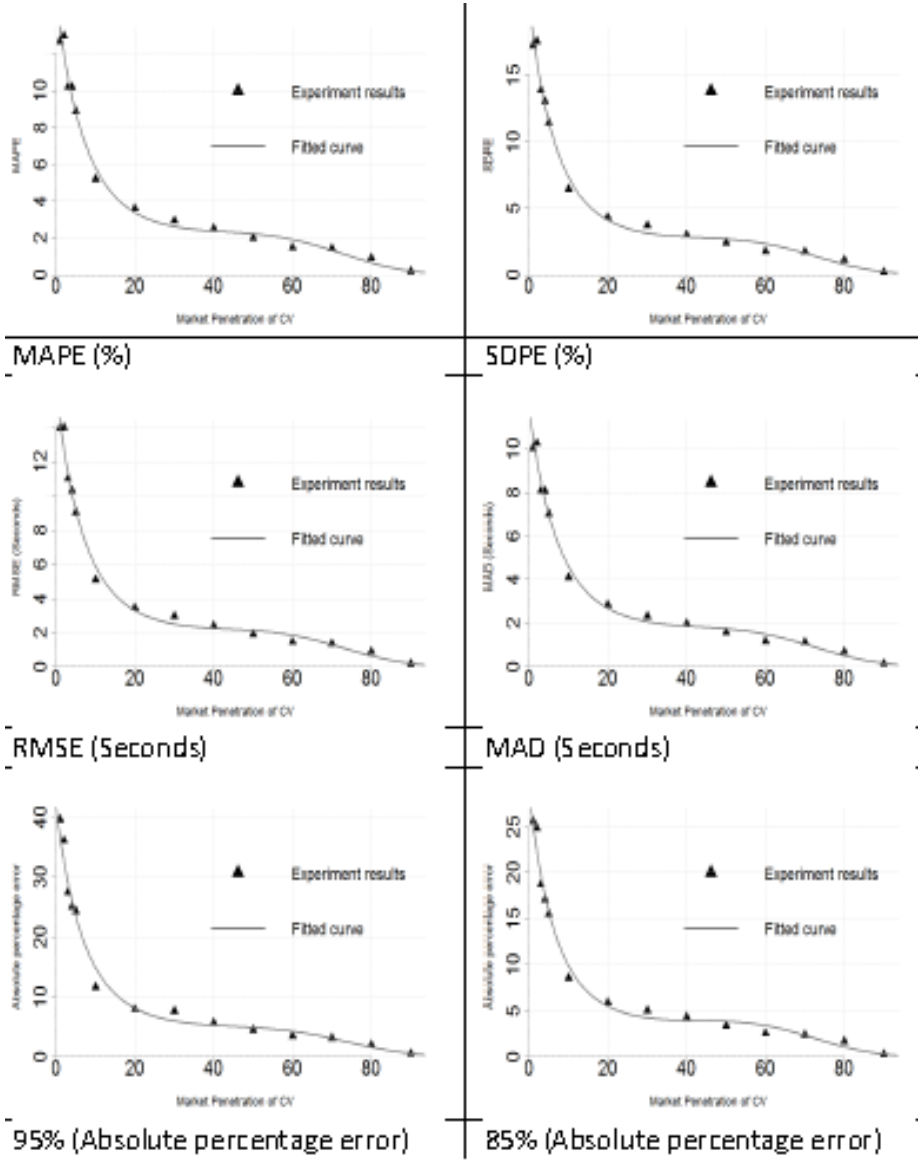




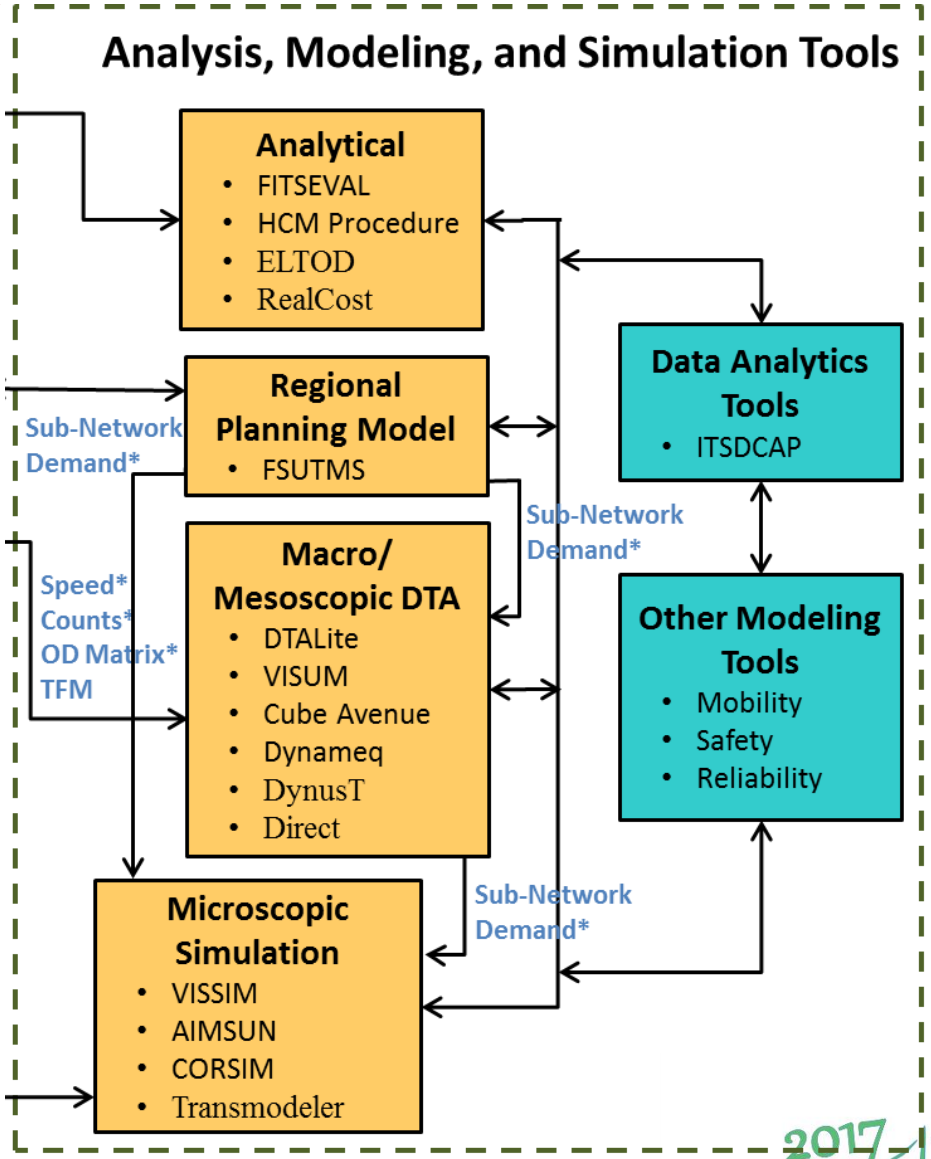
Connected Vehicle Data

- J2735 standards specify a number of message types including BSM and Probe vehicle messages
- Only BSM Part 1 (every 1/10 sec) will be mandated by NHTSA
  - vehicle position, heading, speed, acceleration, steering wheel angle, and vehicle size
- BSM Part 2 have useful elements for DMA applications
  - precipitation, air temperature, wiper status, light status, road coefficient of friction, Antilock Brake System (ABS) activation, Traction Control System (TCS) activation, and vehicle type.
- Probe vehicle data message contains snapshots of vehicle information and sensor data collected from and sent to a vehicle's on-board unit.

TT Accuracy– Congested Arterials



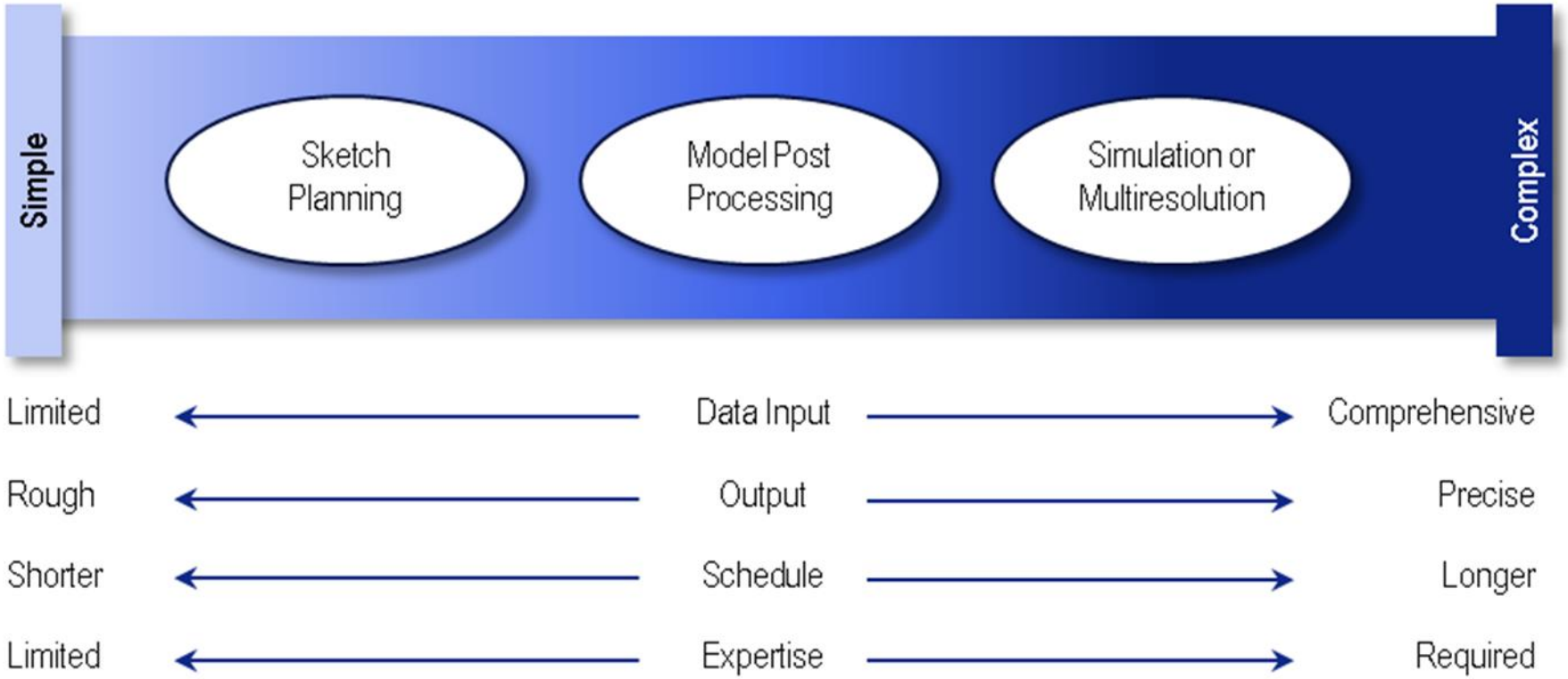
Proposed MRM Framework Components



Analysis Tool Types

- Data processing and data-based analytics
- Regional demand forecasting models
- Land use
- Sketch planning
- Analytical models (called deterministic in FHWA documents)
- Macroscopic simulation models (with and without DTA)
- Mesoscopic simulation-based DTA
- Microscopic simulation (with and without DTA)

Modeling Tool Levels (Source: SHRP 2 L05)



Sketch Planning Tools

- Produce general order of magnitude estimates of travel demand and traffic operations in response to transportation improvements.
- Such tools are primarily used to prepare preliminary benefits and costs.
- Examples: TOPS-BC, IDAS, FITSEVAL

FITSEVAL

- A joint FDOT System Planning Office and FDOT ITS Section effort (accomplished 2008)
- Implemented using Cube script language
- Supports planning process in assessing benefits and costs associated with implementing ITS in given region
- Allows users to assess deployment options within the FSUTMS

ITS Evaluated by FITSEVAL

- Ramp Metering
- Incident Management Systems
- Highway Advisory Radio (HAR) and Dynamic Message Signs (DMS)
- Advanced Travel Information Systems (ATIS)
- High-Occupancy Toll (HOT)
- Toll Lanes
- Signal Control
- Transit Vehicle Signal Priority

ITS Evaluated by FITSEVAL (Cont'd)

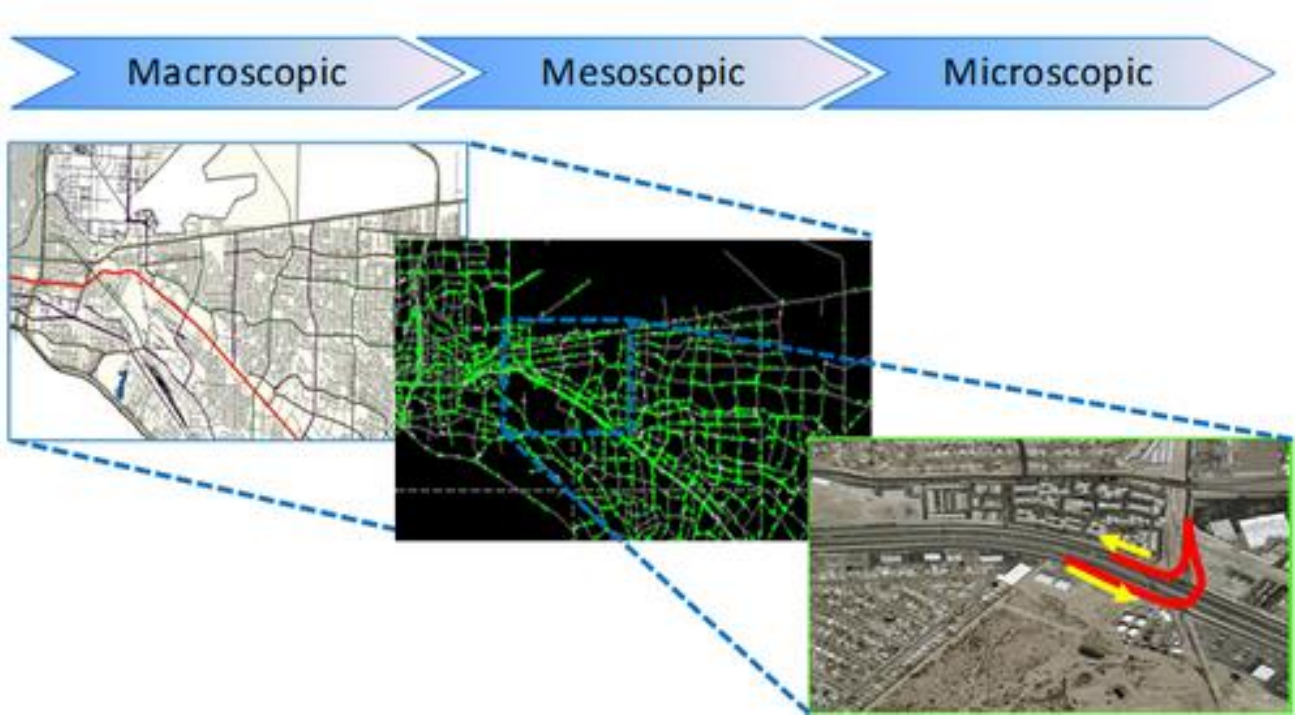
- Emergency Vehicle Signal Priority
- Monitoring and Management of Fixed Route Transit
- Transit Information Systems
- Transit Security Systems
- Transit Electronic Payment Systems
- Smart Work Zones (SWZ)
- Road Weather Information Systems

Why Simulation

- Generate dynamic volumes, travel times, and other measure profiles
- Represent reality under congestion, queuing, and spillback
- Can restrict flow rates not in excess of capacity
  - Demand models allows V/C >>> 1
- Allow assessment impacts of time-variant recurrent and non-recurrent (incidents, work zones, etc.) congestion
- Simulate time-dependent dynamic control, pricing, and management strategies
  - Modeling using API facilities for more detailed modeling
- Can be extended to AV and CV modeling with different market penetrations
- Can be integrated with other applications
  - e.g., signal optimization, DTA, behavioral models (logit), environmental assessment, safety assessment, reliability assessment, etc.

Three Simulation Levels

- Macroscopic
- Mesoscopic
- Microscopic



Why Multi-Resolution

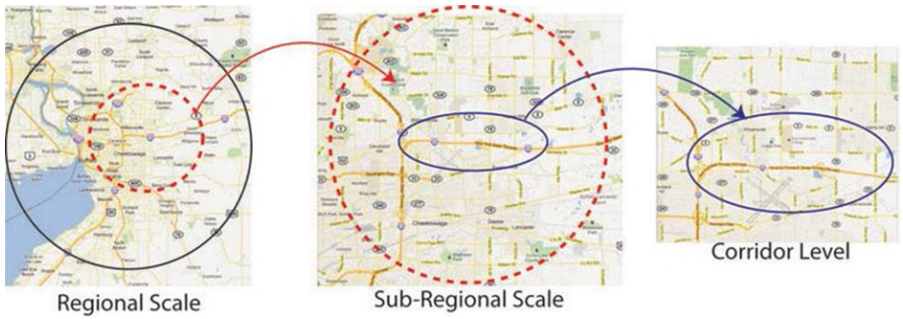
- Static assignment does not produce acceptable level of routing for microscopic simulation
- Traffic demands generated from demand models are not capacity constrained
- Impacts of recurrent congestion and queuing are not well modeled in demand models
- Non-recurrent event impacts are not modeled in demand models
- Strategies such as ML, pricing, and traveler information not well modeled in demand models
- TAZ need to be disaggregated and connectors may need to be reconnected
- Allow multi-scenario modeling (days of the year with different operational scenarios)

Previous Findings

- Sbayti and Roden (2010) compared the use of partial MRM versus full MRM
- In the partial MRM, a subarea from the demand forecasting model is converted to run in a microscopic simulation tool.
  - With this structure, the O-D demands that are departing and entering the boundaries of the sub-area are not capacity constrained.
  - From the macroscopic model's perspective, this results in links with volume to capacity ratios exceeding 1.0.
  - Microscopic models will have difficulty with the utilization of such inputs from the demand model

MRM Applications

- Typical applications use a top-down approach
  - Determine the initial demands and network configuration based on the approved regional demand forecasting process.
  - Use as inputs to mesoscopic simulation-based DTA to determine diversions and bottleneck and strategy impacts on traffic demands.
- Bottom-up applications approach can be used
  - e.g., estimate capacity with CV/AV and signal control using microscopic simulation and feed the results to mesoscopic simulation
- A combination of the two approaches may be needed



Challenges to Effective MRM

- Need for supporting tools that automate parts of the process
- Limited knowledge and experience, particularly with DTA-based mesoscopic tools.
- Some of the effective DTA-based tools are still academic and research tools
- Need for knowledge transfer and documentation
- Challenges in calibration large networks including demands (particularly for future years) and supply calibration and validation
- The need to disaggregate the zones and connectors coded in demand models

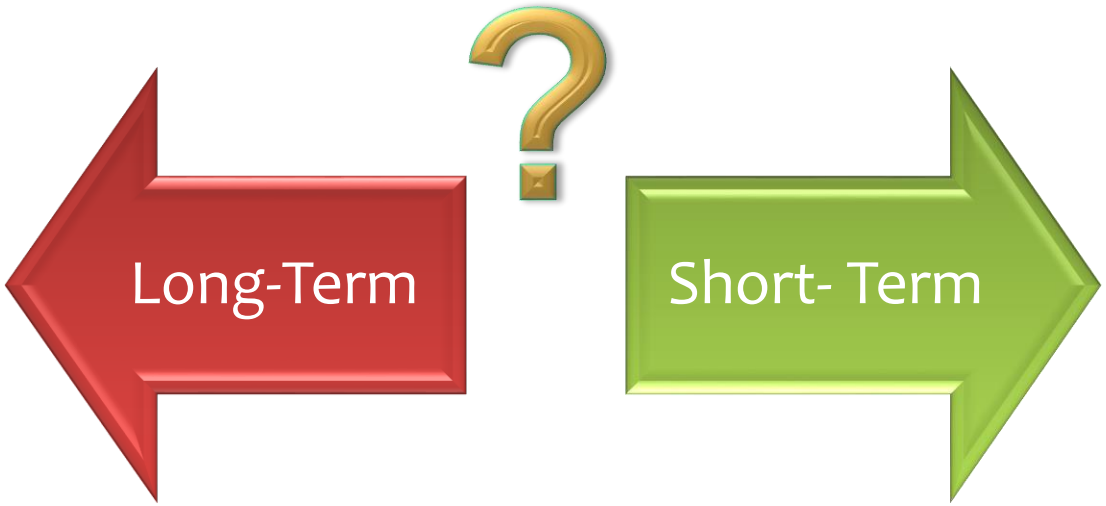
Strategic Travel Choices

- What kinds of travelers and choices do we need to represent? Example is below

- Who are the travelers traversing the network?
- How do we apply DTA techniques, possibly combined with other behavioral models to model each subset of the traveler population?

Two Different Choice Categories

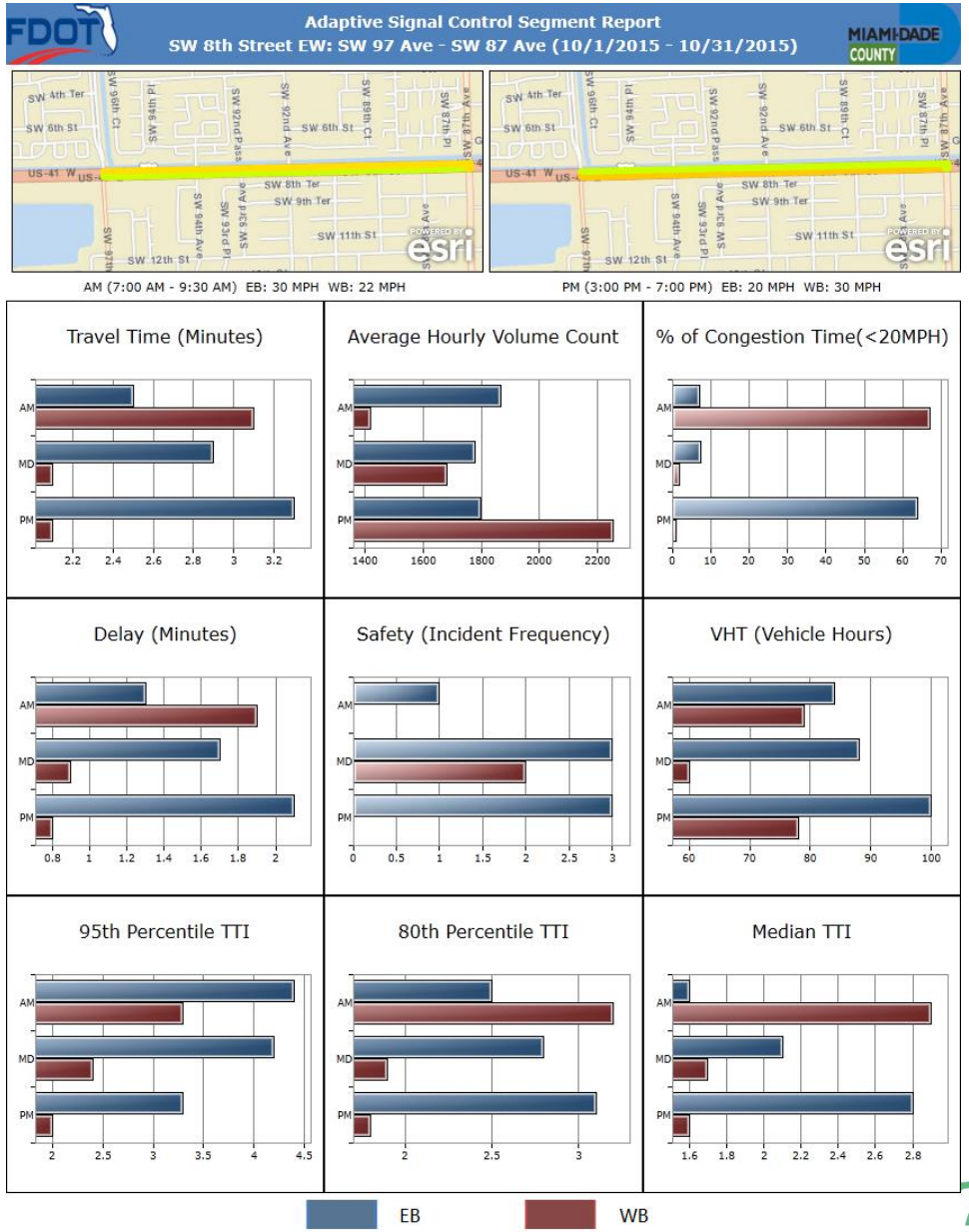
- Choices based on day-to-day learning and adaption
- Other choices (tourists, diversion due to incidents, work zones, response to VSL and queue warnings, etc.)



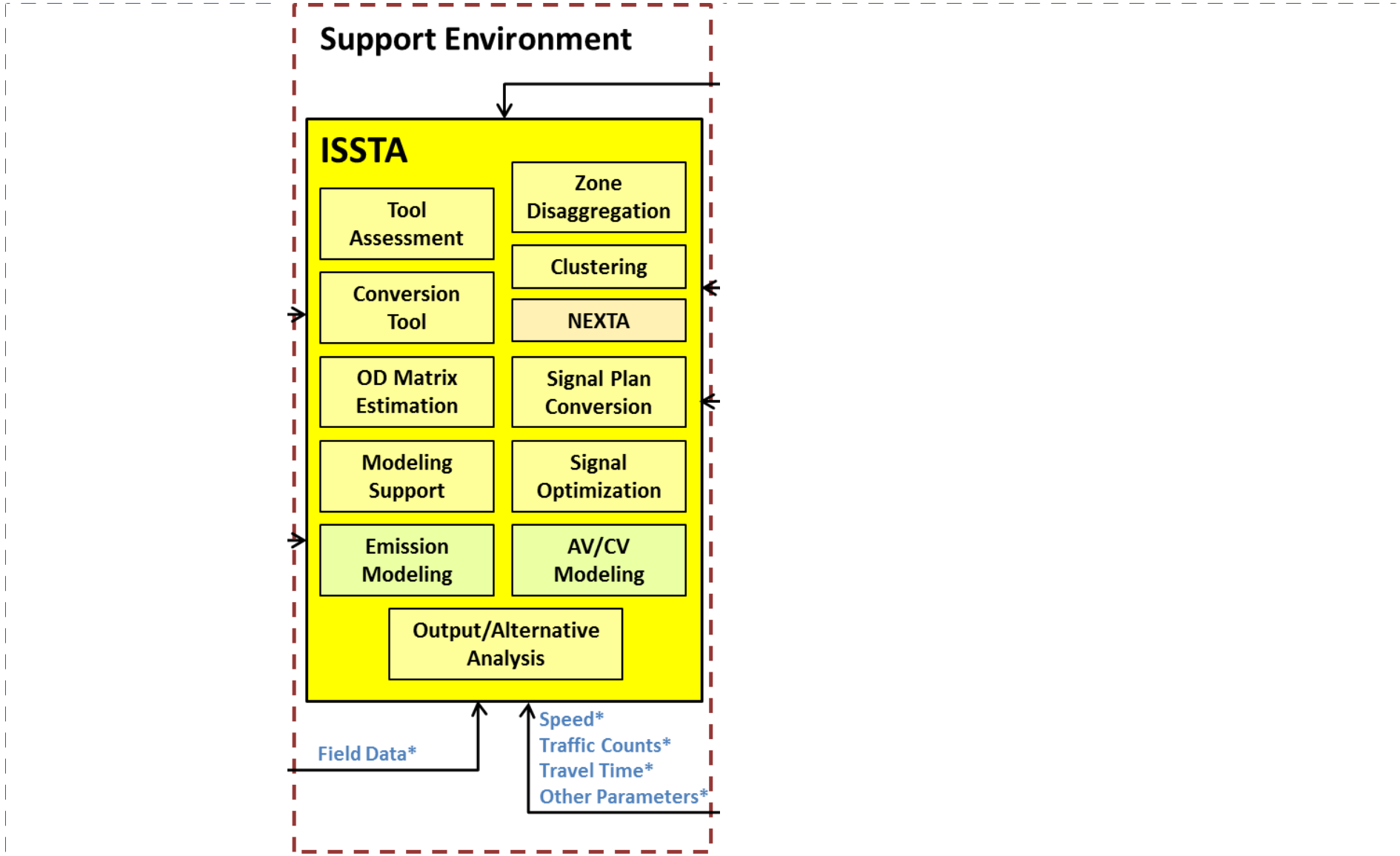
Data Analytic Functionality

- Aggregation and cleaning of data from multiple sources
- Grouping and clustering of data
- Performance measurements and dashboard
- Real-time information sharing
- Prediction of system performance and impacts
- Decision support tools
- Benefit-cost analysis of advanced strategies
- Transportation model support

Performance Dashboard



Proposed MRM Framework Components



Supporting Tools

- Tool Assessment
- Conversion tools
- ODME
- Zone and connector disaggregation
- Traffic pattern clustering and aggregation
- Signal modeling support
- Calibration and convergence support
- Emission modeling
- Reliability modeling
- Safety modeling
- Decision support (output visualization and alternative analysis)
- Possibly land use tools (SHRP 2 C10 A and B projects)

Example of Tool Selection Criteria

Criterion	Cube Voyger	ELTOD	DTALite	Cube Avenue	VISSIM
Shortest Path and Path Choice					
Assignment Type					
En-route Dynamic Routing (e.g., Dynamic Navigation System)					
Specification of Fine-Grained Assignment Interval (e.g., 15-30 minutes)					
UE Assignment Method					
Allows Fixing Paths for Parts of the Demands					
Outputting and Using Interval-based Convergence Gap					
Assignment of Individual Vehicles					
Assignment of Multiple Demand Types					
Traffic Flow Model (TFM)					
Model Type					
Queuing and Spillback					

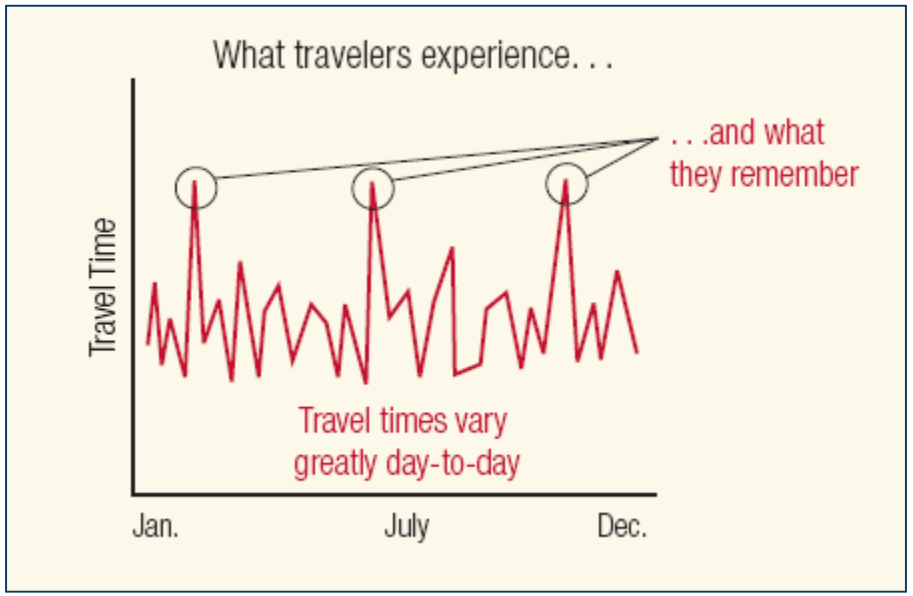
Example of Tool Selection Criteria

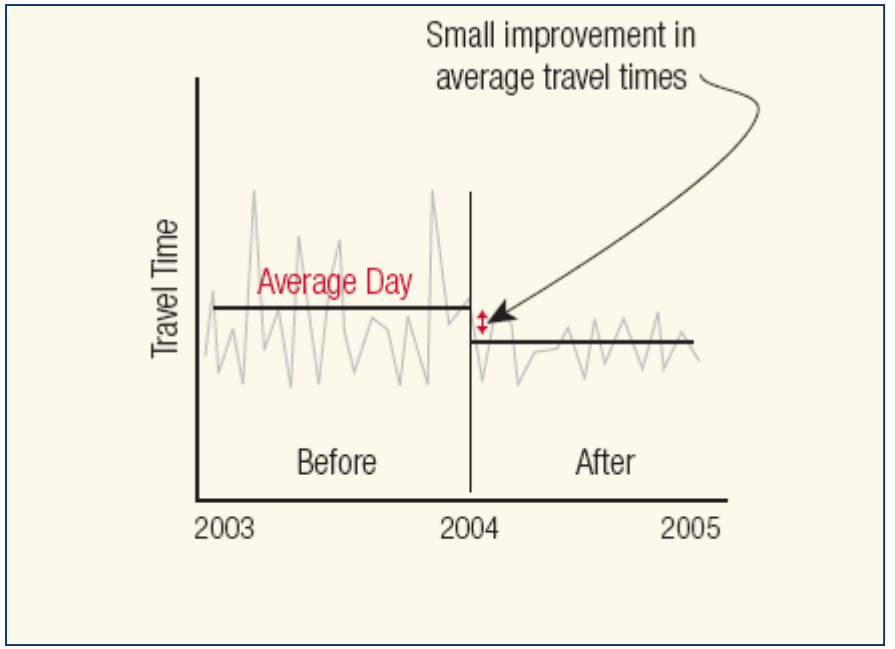
Automatic Calculation of Signal Timing					
Lane-by-Lane Simulation					
Merging/Weaving Simulation					
ML and ACC/CACC Modeling					
Generalized Cost in Assignment					
Willingness-To-Pay (WTP) Combined with Assignment					
Link Access Restrictions/Prohibitions by Vehicle Type					
Modeling Managed Lanes and Reversed Lanes					
Fixed and Time-of-Day Pricing by User Types					
Dynamic Pricing					
In Homogenizing of VOT and VOR					
Feedback to Regional Planning					
Capacity as a Function of Proportion of Vehicle Types					

Estimation of Other Measures

- Traditionally traffic modeling tools produced mobility measures: VMT, VHT, travel times, queues, etc.
- Increasing interest in other measures that predict safety performance for planning, planning for operations, and operations
- Prediction can be also at macroscopic, mesoscopic, and microscopic levels
  - Reliability
  - Safety
  - Emission

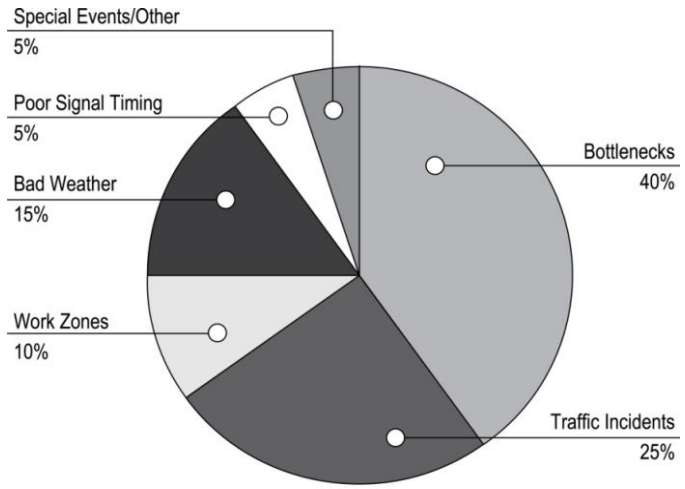
Why Modeling Reliability is important





Unreliability Modeling

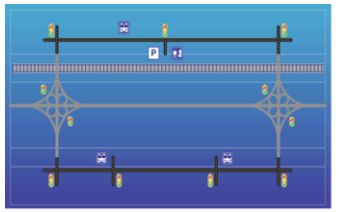
- Seven factors cause travel times to be unreliable
  - Incidents
  - Inclement weather
  - Work zones
  - Special events
  - Traffic control device timing
  - Demand fluctuations
  - Inadequate base capacity



- SHRP 2 tool and methods: L02, L04, L07, L08, C11

Modeling of Advanced Management Strategy

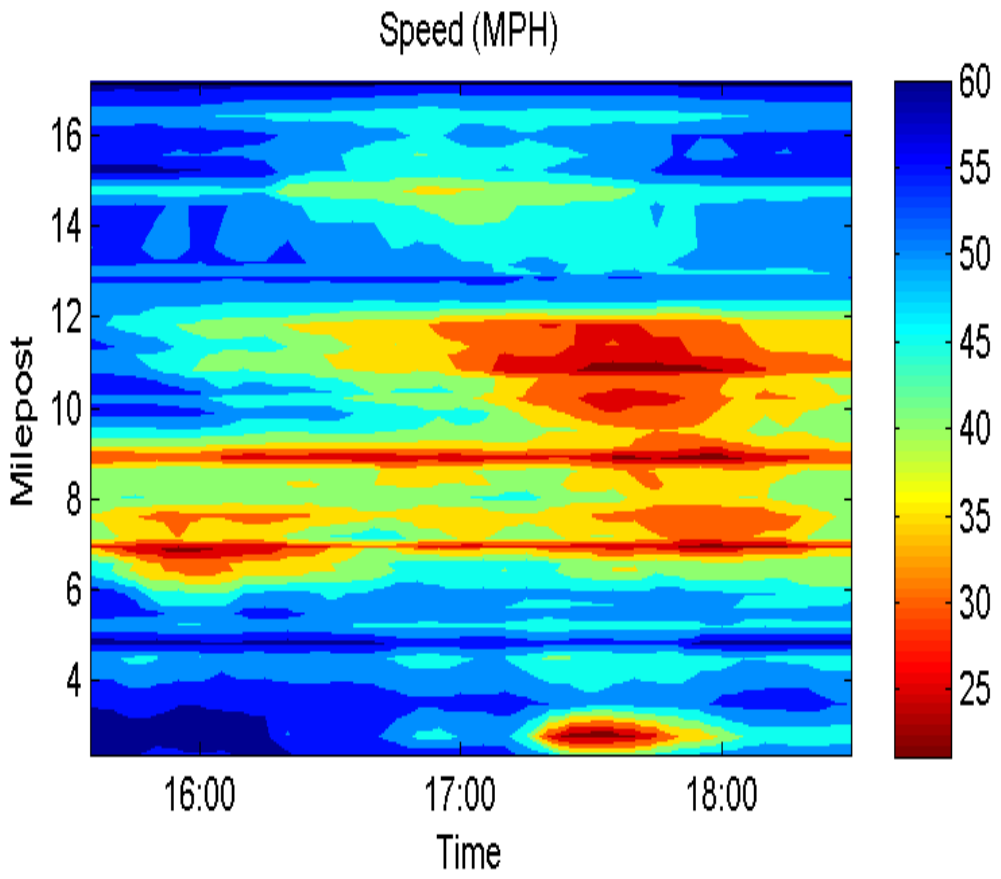
- Active traffic and demand management (ATDM): Dynamically monitor, control, and influence travel, traffic, and facility demand of the entire transportation system and over a traveler's entire trip chain
- Dynamic mobility applications (DMA) improve mobility and reliability based on emerging technologies such as AV and CV
- Integrated corridor management (ICM): Improvement of operational efficiency based on coordinated operations between facilities and modes. Promotion of cross-network shifts.



Source: USDOT Integrated Corridor Management Web Site (http://www.its.dot.gov/icms/)

Case Study: Application to Managed Lane Modeling

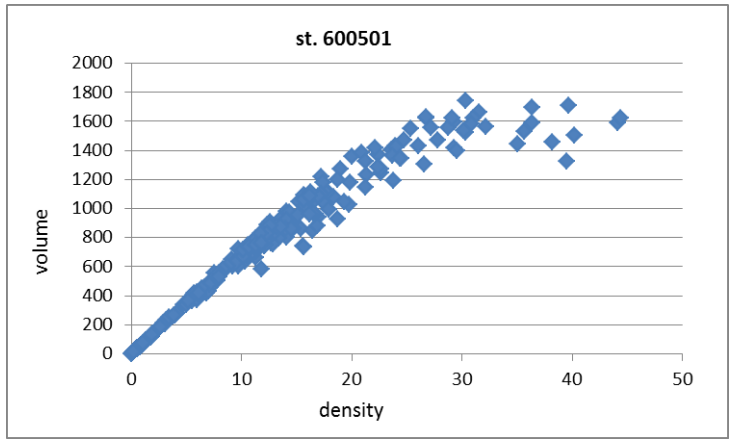
Supply Calibration - Bottleneck

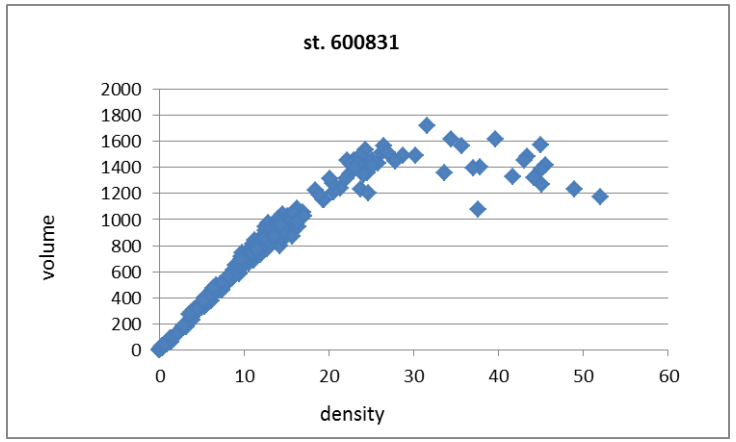


- Stations 600561, 600711, and 600921 were recognized as potential bottlenecks

Capacity

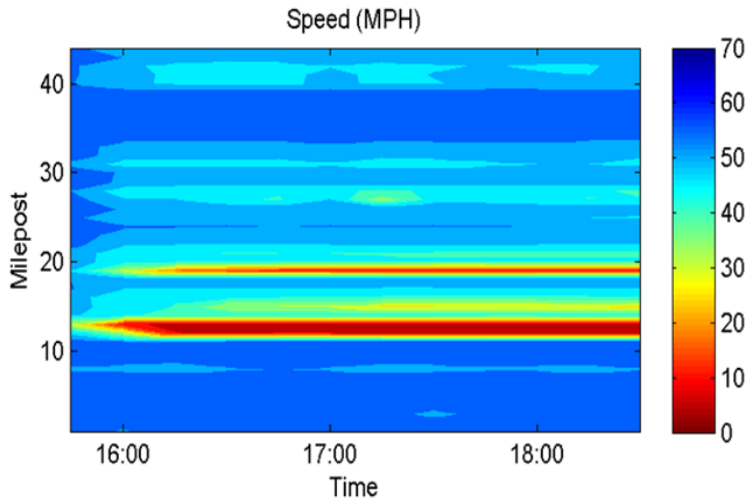
- Capacity is modeled as pre-breakdown flow before breakdown happens, and as queue discharge for after breakdown
- Capacity of GPL is about 1,830 vphpl and of managed lane is 1650 veh/hr/lane.



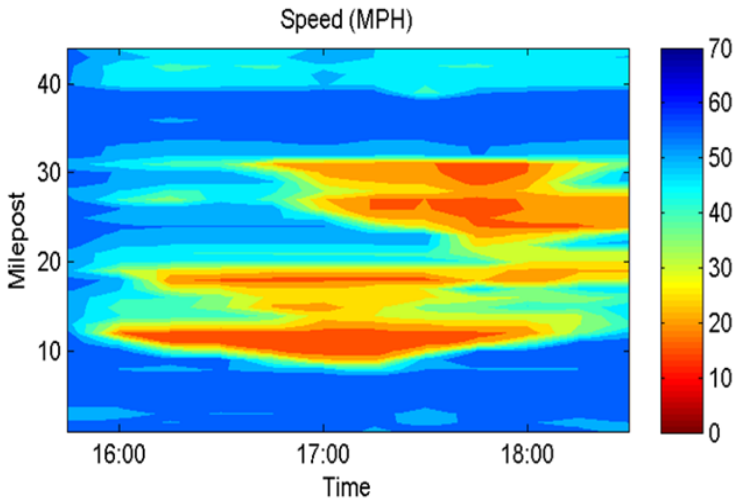


Calibration Impacts

- Calibrating capacity and jam density successfully replicated bottleneck locations and impacts

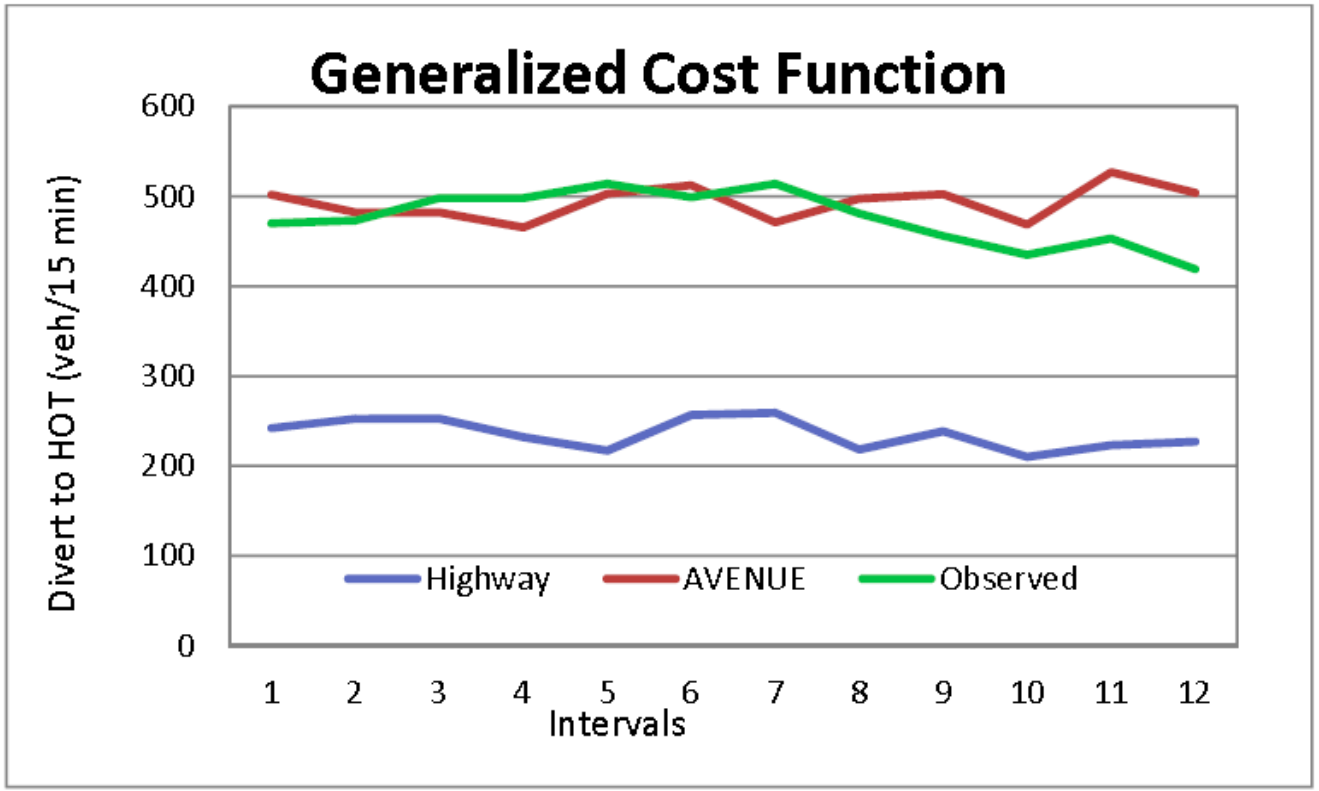


Storage Density=190 veh/ln/mi

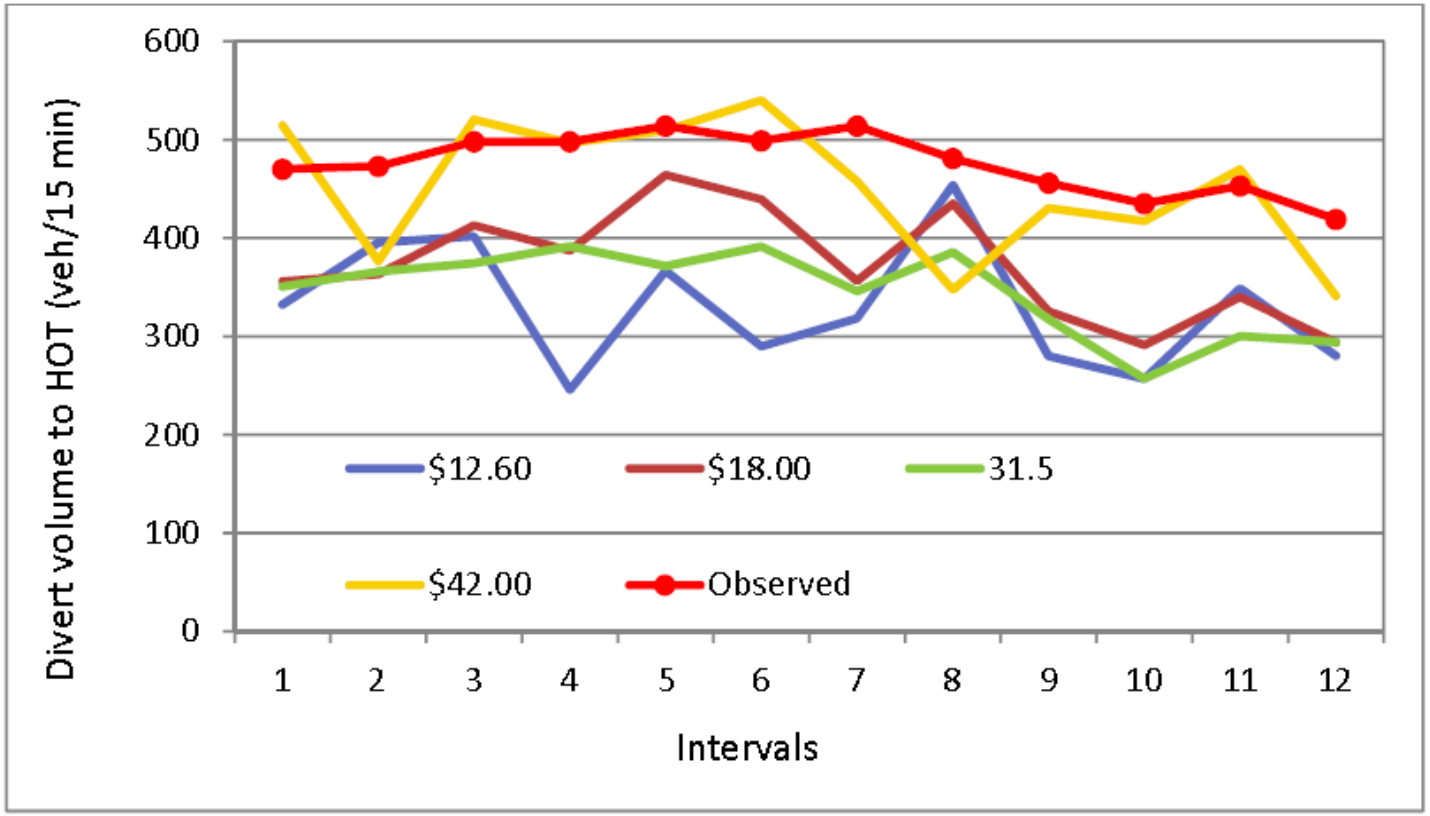


Queuing Density=55 veh/ln/mi

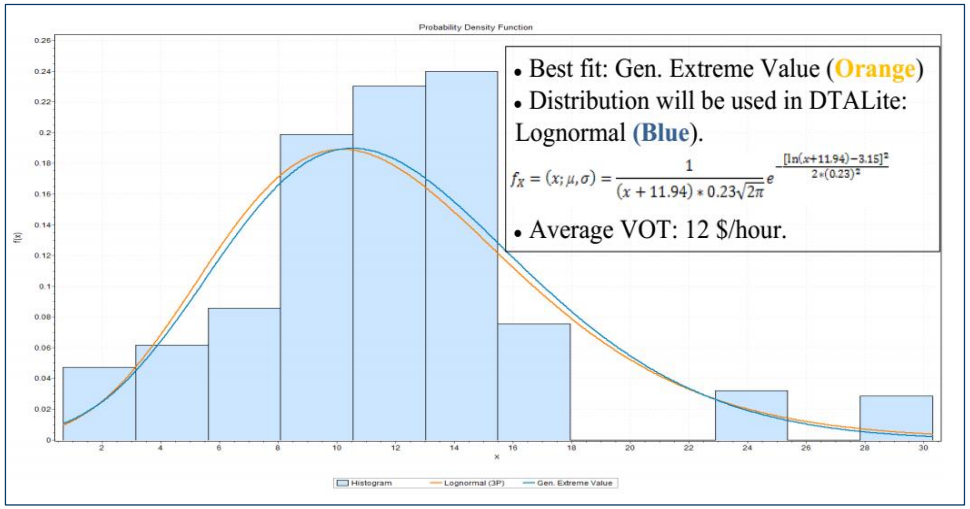
DTA versus STA Results



Impact of VOT –Cube Avenue



ML Modeling VOT Distribution

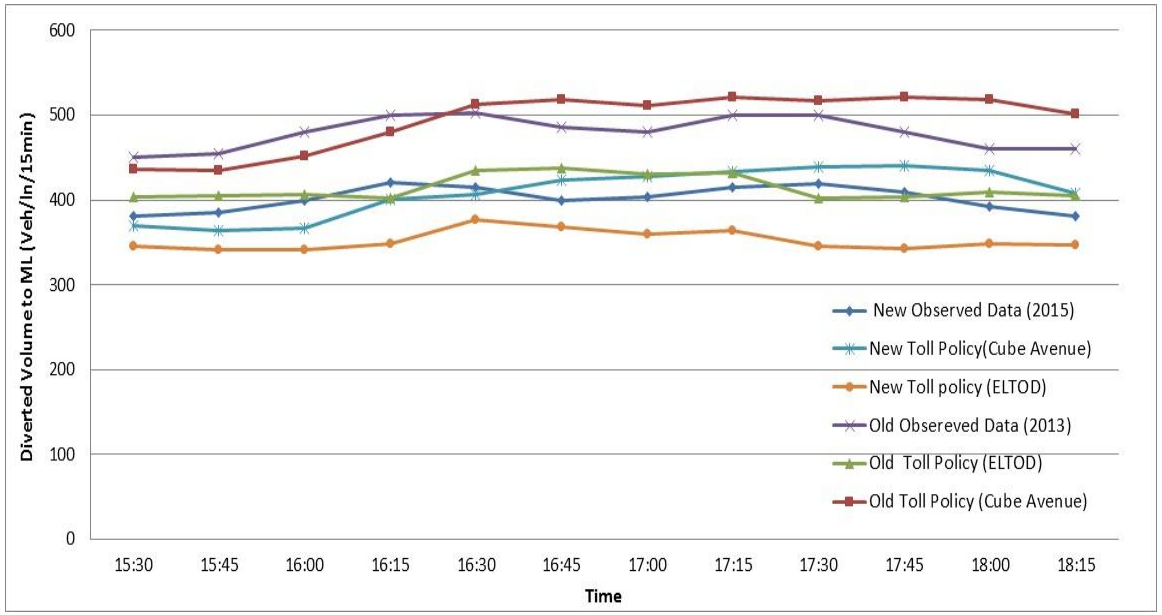


Goodness-of-Fit Statistics	Value of Time $ (VOT)					
	$12	$20	$30	$40	$50	$40 Fixed (without Distribution)
MAPE (%)	16.50	9.70	11.86	4.01	5.73	9.03
RMSE(veh/ln/15min)	73.94	41.76	52.11	18.11	26.60	40.34

Impact of VOR Use

Goodness-of-Fit Statistics		ELToD	Meso	Macro
With Consideration of VOR	RMSE (veh/ln/15min)	12.00	8.23-9.18	10.77
	MAPE (%)	2.29	1.89-1.96	2.27
Without Consideration of VOR	RMSE (veh/ln/15min)	54.30	40.34-46.22	37.03
	MAPE (%)	13.36	9.03-11.29	8.68

Can Models Predict ML Shifts

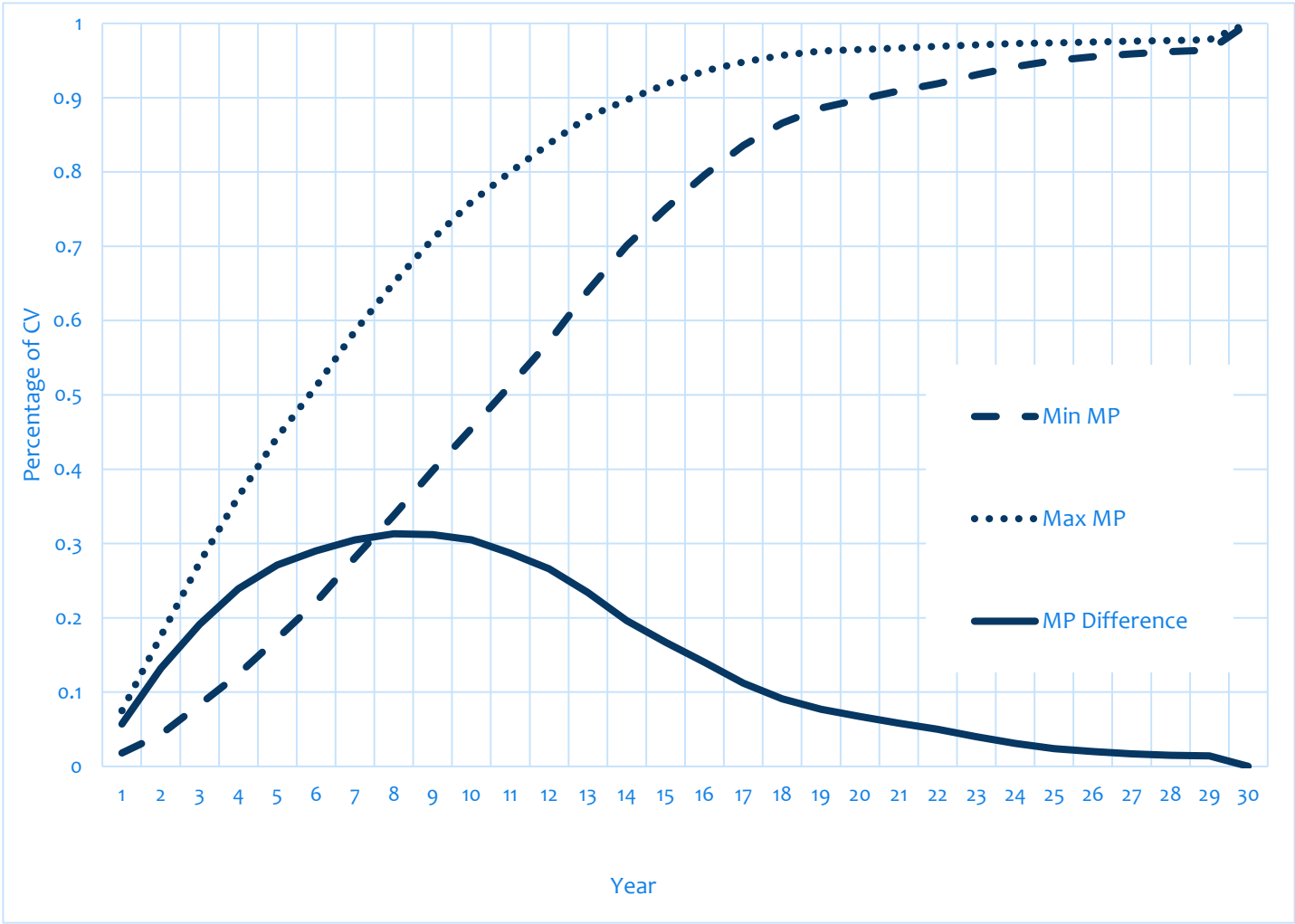


Goodness-of-Fit Statistics		Fixed Pricing and Static Assignment (ELTOD)	Dynamic pricing with Dynamic Assignment (Avenue)
New Toll Policy	RMSE (veh/ln/15min)	51.42	25.15
	MAPE (%)	12.22	5.87
Old Toll policy	RMSE (veh/ln/15min)	67.39	31.04
	MAPE (%)	13.48	5.90

Macro+Meso+Micro Modeling

- Waiting for I-95 Model from FDOT D6

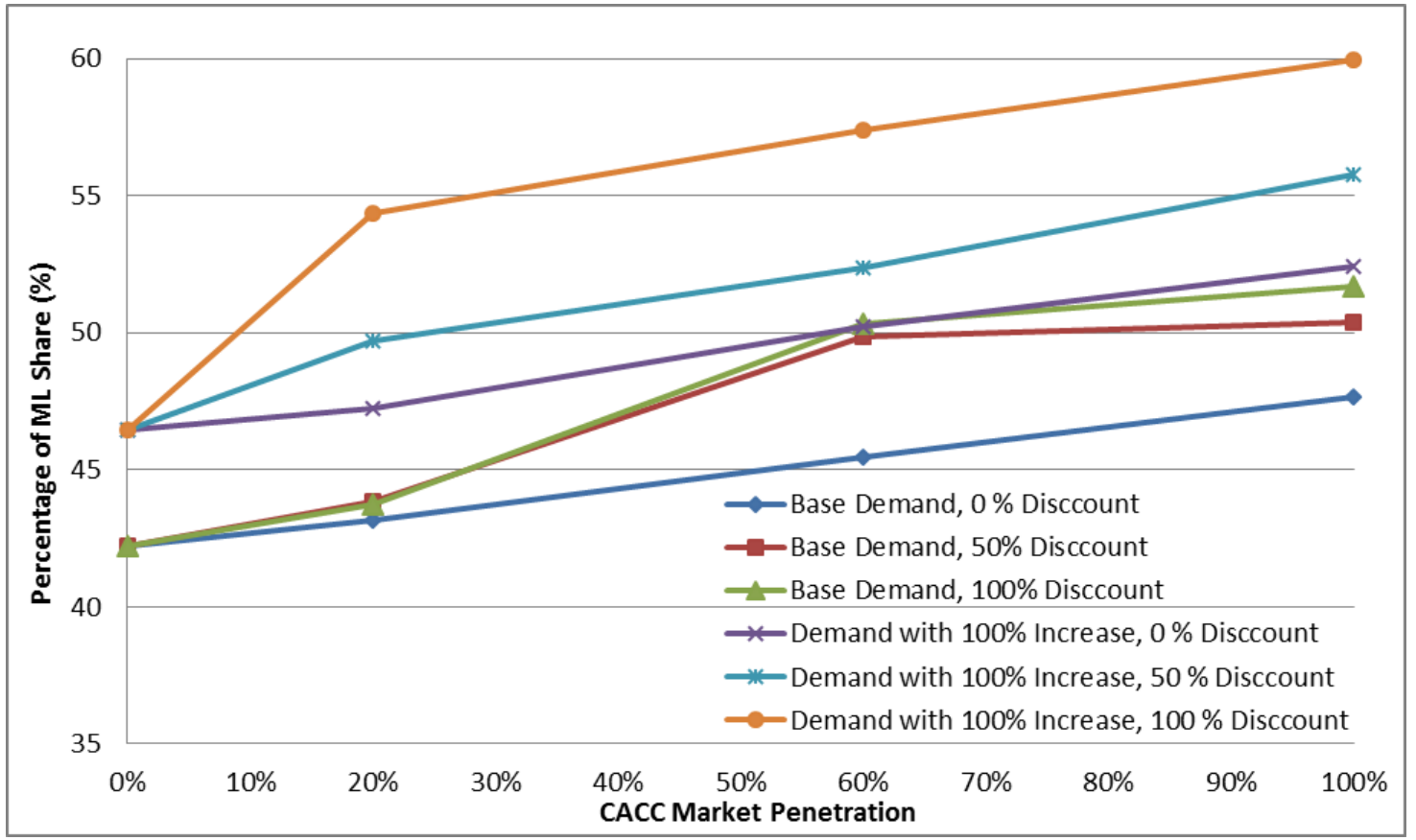
Estimation of CV MP



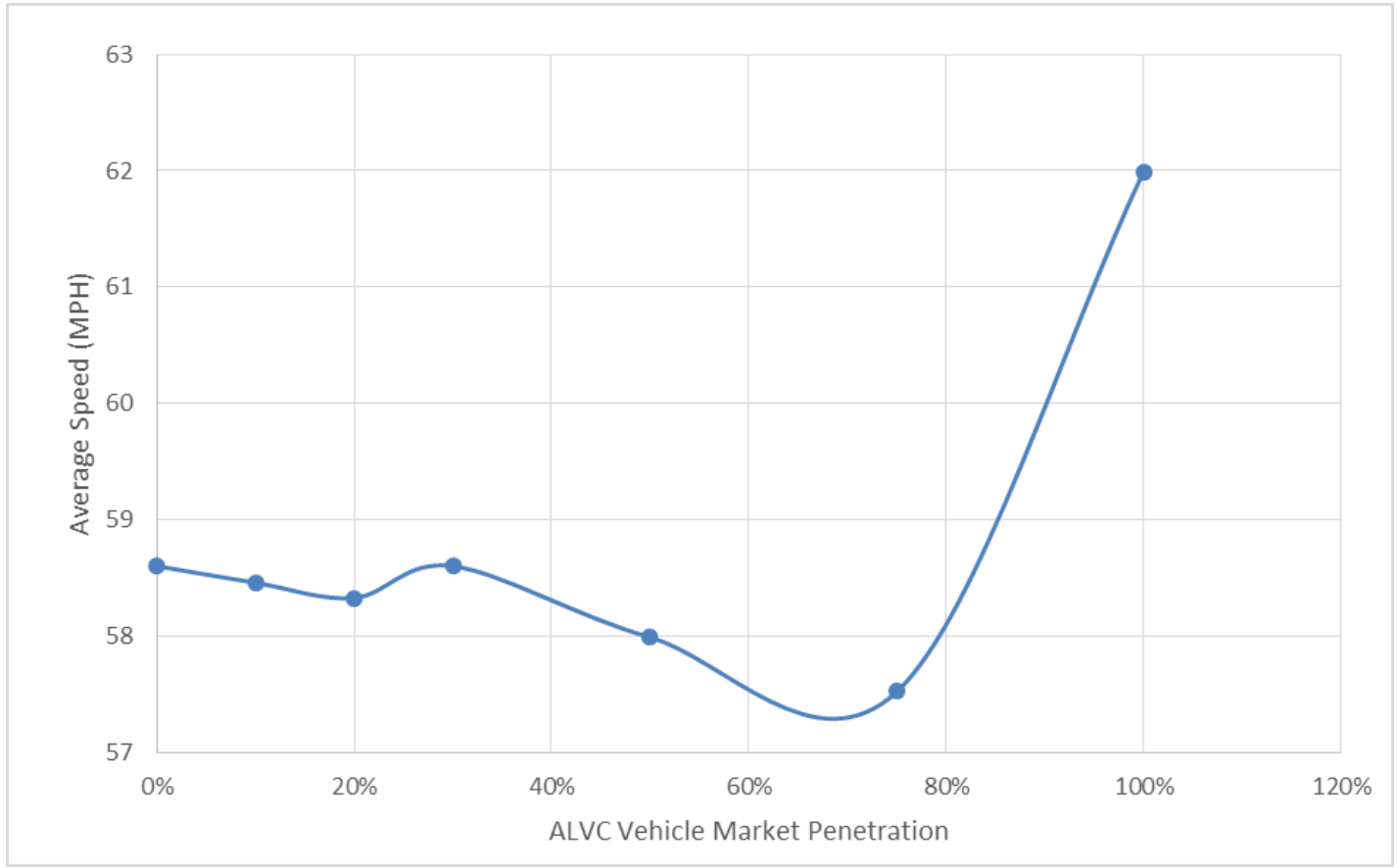
Estimation of CV MP on Capacity

Percentage of CACC Vehicles (%)	Lane Capacity (veh/ln/hr)
0	2018
0	2092
40	2230
60	2500
80	2890
100	4000

Impact of CACC on ML Using Meso-based DTA



Impact of CACC on the Merging Segment Using Micro



Thank You !

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